State of California

THE RESOURCES AGENCY

Department of Water Resources

BULLETIN No. 162

BOX CANYON PROJECT

Feasibility Study

DECEMBER 1965

HUGO FISHER
Administrator
The Resources Agency

EDMUND G. BROWN
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TE OF CALIFORNIA—RESOURCES AGENCY
PARTMENT OF WATER RESOURCES
. BOX 388
RAMENTO
WILLIAM E. WARNE, Director

October 8, 1965

Honorable Edmund G. Brown, Governor
and Members of the Legislature
of the State of California

Gentlemen:

Bulletin No. 162, "Box Canyon Project Feasibility Study", reports on a 2-year investigation of a dam and reservoir project on the Sacramento River about 2 miles southwest of Mt. Shasta City.

This feasibility study was authorized by the Legislature after Department of Water Resources Bulletin No. 100, a reconnaissance report on the water resources in the Mt. Shasta City-Dunsmuir area, indicated that the Box Canyon Project was justified.

The project, as presented herein, would (1) provide an opportunity for water-associated recreation activities, (2) greatly enhance the present trout fishery, and (3) provide incidental flood control downstream from the dam in the vicinity of Dunsmuir.

As a result of the investigation, it is concluded that a dam and reservoir at the Box Canyon site is engineeringly feasible, and that the project is economically justified. The project is financially feasible if a local agency will assume responsibility for the project, and if that agency can obtain construction funds through State and Federal grants and loans or through the sale of local bonds.

The recreation features of the project could be operated and maintained by the local agency or by the State as a unit of the State Park System.

Sincerely yours,

William E. Warne

Director

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Fish and Wildlife studies were conducted by
The Department of Fish and Game, Water Projects Branch

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The assistance and data contributed by many agencies and private individuals during this investigation are gratefully acknowledged.

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Mr. Shasta City Public Works Department

Southern Pacific Company

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An artist's conception of Box Canyon Reservoir is shown in the foreground. Mt. Shasta City and Interstate 5 are in the center of the photograph, and snow-covered Mt. Shasta is in the background.

CHAPTER 1. SUMMARY

In the past, water development projects have been constructed principally for irrigation, municipal and industrial water supplies, flood control, and hydroelectric power production. However, in recent years equal recognition has been given to other purposes of water development -- water-associated recreation and enhancement of fish and wildlife.

The Box Canyon Project, located high in the scenic watershed of the Sacramento River about 2 miles southwest of Mt. Shasta City in Siskiyou County, is being proposed almost exclusively for recreation and fisheries enhancement.

Box Canyon, a narrow, steep-walled gorge, will provide the abutments for Box Canyon Dam. Construction of a dam in this rugged canyon, to reduce flooding during the winter and to provide an attractive recreation area in the summer, has been recognized as an economic possibility for several years.

This report presents a plan whereby construction of the Box Canyon Project could become a reality within the very near future.

Background

In 1952, the California-Oregon Power Company studied the site for a power development but found that it did not satisfy their requirements. In 1957, the Department of Water Resources designated Wagon Valley Reservoir, with the damsite located in Box Canyon, as a possible project to divert water from the Sacramento River into the McCloud River Basin to be used for hydroelectric power generation.

In 1958, residents of the Mt. Shasta City--Dunsmuir area urged, through their County Supervisors and State Legislators, that a study of water resources in their area be made by the Department of Water Resources. Subsequently, the Department conducted a short survey and, in January 1959, published a report entitled "Report on the Desirability of Investigating the Box Canyon Dam and Reservoir Project in Siskiyou County". The report concluded that an investigation was warranted.

In 1960, the California Legislature authorized the Department to conduct a reconnaissance investigation to study the engineering and economic justification of a water resources development program for the Mt. Shasta City--Dunsmuir area which would include a multiple-purpose dam and reservoir at the Box Canyon site. During the reconnaissance study it was found that a dual-purpose recreation and fishery enhancement project which included Box Canyon Dam and Reservoir had indications of economic justification and engineering feasibility. The report of that study, published in preliminary edition in March 1963 as Bulletin No. 100, "Mt. Shasta City--Dunsmuir Area Investigation", recommended that further study be made of the Box Canyon Project.

In 1963, the Legislature directed the Department of Water Resources to complete a final feasibility study of the Box Canyon Project. This bulletin reports on the results of the feasibility study.

Objectives and Scope

The objectives of this feasibility study were to determine (1) engineering feasibility, (2) economic justification, and (3) financial feasibility of the Box Canyon Project. To accomplish these objectives intensive engineering, economic, fish, wildlife, recreation, and geologic studies were required.

The reconnaissance study reported on in Department of Water Resources Bulletin No. 100 concluded that the project showed indications of engineering feasibility and economic justification. However, those conclusions were based on reconnaissance information which gave only tentative indications of such items as subsurface geologic conditions at the damsite, suitability of proposed construction materials, and recreation and fisheries enhancement possibilities.

Much of the current feasibility study was devoted to subsurface exploration of the damsite, to exploration and testing of possible construction materials, and to detailed evaluations of recreation and fisheries enhancement.

Conclusions

The following conclusions are based on analyses of data collected and developed for this investigation and on the various available methods which might be used to finance the project.

1. The portion of southern Siskiyou County surrounding the proposed Box Canyon Project is a scenic recreation area which has a climate ideally suited for both summer and winter recreation. The area may be reached by both surface and air transportation and is being visited by increasing numbers of recreationists each year.

2. Runoff from the 122-square-mile drainage area tributary to the Box Canyon Reservoir site is estimated to average 160,000 acre-feet annually under year 2020 conditions of upstream development. This water supply will be adequate to satisfy requirements of reservoir operation for recreation and fisheries enhancement.

3. The primary purposes justified for inclusion in the project are recreation and fisheries enhancement. There will be no demand for project water for irrigation or municipal and industrial purposes in the foreseeable future. However, if a demand for municipal and industrial water should develop, sufficient water would be available for these purposes without significantly altering the operation of the reservoir for recreation and fisheries enhancement.

4. Some flood control benefits would be derived as an inherent consequence of operating the reservoir for recreation and fisheries enhancement. However, a large flood storage reservation in the reservoir or a large flood control outlet works is not justified because the costs of providing these features would exceed the estimated benefits.

5. The project selected for optimum development would consist of a 209-foot-high zoned embankment-type dam capable of storing 26,000 acre-feet of water at a normal pool (spillway lip) elevation of 3,181 feet, USGS datum. The water surface area at normal pool elevation would be 430 acres.

6. A total of 2,240 acres would be required to provide adequate project lands for the dam and reservoir, including those lands developed for water-associated recreation facilities and for preservation of wildlife. With the exception of 80 acres owned by the federal government, this land is all in private ownership.

7. The project is engineeringly feasible. It can be safely constructed using accepted techniques.

8. The Box Canyon Project is economically justified as of December 1964. On a present worth basis, the project benefits ($11,571,000) exceed the project costs ($11,076,000) by a ratio of 1.04 to 1.0. Secondary benefits accruing to the local area would stimulate the local economy.

9. The Box Canyon Project appears to be financially feasible. Federal and state recreation and fisheries enhancement programs could provide a local agency with funds to cover the entire construction costs of the project. The project could be operated and maintained by the State Department of Parks and Recreation.

10. The most logical plan for implementation of the Box Canyon Project appears to be for a local agency (1) to accept responsibility for construction of the project, (2) to seek grants of construction funds from federal and state programs, and (3) to arrange for the State Department of Parks and Recreation to operate and maintain the project after it is constructed.

Recommendations for Project Implementation

For the Box Canyon Project to be constructed as soon as possible, it is recommended:

1. That Siskiyou County adopt the plan of development for the Box Canyon Project substantially as presented in this bulletin, and that the county designate a responsible agency as sponsor of the project.
2. That the sponsoring agency proceed as follows:

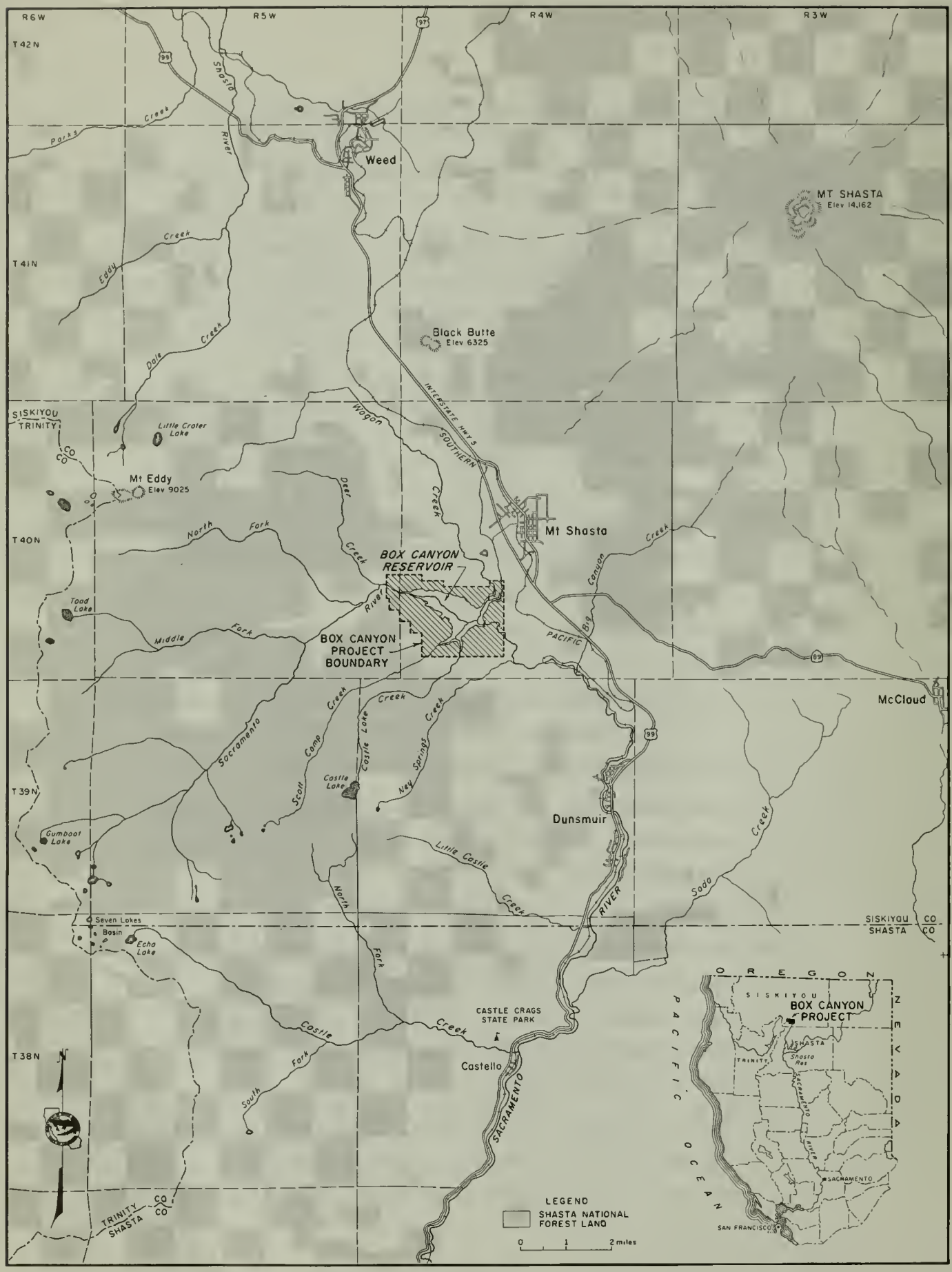
    a. Submit a letter of application to the Department of Water Resources requesting a construction grant in the amount of $4,117,000, the letter to be accompanied by this feasibility report and a resolution adopted by the designated local agency specifically authorizing filing of the application.

    b. Submit an application to the Administrator, Resources Agency of California, requesting a construction grant from the federal government, under provisions of the Land and Water Conservation Fund Act of 1965, or the Public Works and Economic Development Act of 1965.

    c. Make immediate application to the State Water Rights Board for a license to store water at the Box Canyon Reservoir site.

    d. Submit applications to the State Department of Parks and Recreation requesting that agency to operate and maintain the recreation features of the project. Study the possibility of local operation and maintenance of the project in the event the State is not able to function as operator.

    e. Either purchase or take option to purchase the required project lands, or attempt to prevent further escalation of land values through adoption of zoning ordinances.



PROJECT LOCATION MAP

CHAPTER 2. INTRODUCTION TO THE PROJECT AREA

The proposed Box Canyon Project is located about 60 miles north of Redding and 2 miles southwest of Mt. Shasta City, near the headwaters of the Sacramento River. The area included in the proposed project boundary ranges in elevation from 3,000 to 3,600 feet above sea level and is mostly covered with pine and fir forests interspersed with stands of hardwoods.

Present development within the project boundary is generally limited to agriculture, gravel production, and lumbering. However, there is activity toward subdividing a small portion of the area for both permanent and vacation homesites.

Evaluation of a water project generally requires that an area larger than the project boundary be studied to determine the need for project services, the amount of water and other resources available for development, access routes to the project, population densities, and other economic, engineering, and sociologic factors which might influence project development. The area which would exert the greatest influence on the Box Canyon Project, and in turn would be greatly influenced by project development, is that portion of Siskiyou County bounded by Weed on the north, McCloud on the east, Dunsmuir on the south, and the Trinity River--Sacramento River divide on the west. Further discussion in this bulletin will refer to this area as the project area. The project location map on the facing page shows the area and some of the major geographical features.

A great portion of the project area is mountainous and covered by pine and fir forests. Much of this area is owned by the federal government and managed by the U. S. Forest Service. Government lands in the Shasta National Forest are shown in light gray on the project location map.

The Box Canyon damsite lies just below the junction of the Sacramento River and Wagon Creek. The Sacramento River heads at Gumboot Lake and flows east to this junction. Wagon Creek heads further north on the slopes of Mt. Eddy and flows east just south of a saddle between the Sacramento River drainage basin and the Shasta River drainage basin. It turns south and, as it flows through Wagon Creek Valley to the junction point, picks up the flow

of many springs from the slopes of Mt. Shasta. The drainage area tributary to Box Canyon Reservoir ranges in elevation from 3,000 feet at the damsite to 9,025 feet at Mt. Eddy and to a spectacular 14,162 feet at Mt. Shasta.

The forest cover, fishable streams, and scenic mountains contribute to the natural recreation attractiveness of the project area. Box Canyon Reservoir would complement this already beautiful natural area.

Climate

The mild summer climate in the vicinity of Mt. Shasta is a definite advantage to the recreation potential of this area. Summer temperatures reach an average high of 85°F. at Mt. Shasta City, and usually rise above 90°F. only 18 days a year. Nighttime temperatures are cool.

Temperatures drop below freezing about 137 days a year, with an average low temperature of 24°F. during the winter.

Although the summers are dry, heavy precipitation occurs over the basin from October to June. The average precipitation for the entire drainage basin above Dunsmuir is about 50 inches a year. Average precipitation ranges from about 34 inches at Mt. Shasta City to more than 60 inches at higher elevations. Plate 1 shows the variation of annual precipitation in the Sacramento River drainage basin above Shasta Lake. Much of this precipitation occurs as snow which, at higher elevations, remains on the ground until summer. Average annual snowfall at Mt. Shasta City is 102 inches; however, the depth of snow on the ground rarely exceeds 2 feet.

Population

Four towns, Mt. Shasta City, Weed, Dunsmuir, and McCloud, lie within the project area. According to the 1960 census, the population of Mt. Shasta City was 1,963, Dunsmuir 2,873, McCloud 2,140, and Weed 3,223. In contrast to the expanding population of many other California cities, the population of each of these four towns has remained nearly constant during the past 20 years. However, as California's growing population seeks more space, the northern counties, and in turn these cities, will experience a population increase.

The 1960 population of the area within a 10-mile radius of the Box Canyon Project was about 7,500. Present estimates are that the population in this area will grow to about 27,000 within the next 50 years.

Present Development

Residents of the area which surrounds the project have traditionally depended upon lumber, the railroad, and, to a lesser extent, agriculture for their livelihood. Although the lumber and railroad industries have declined in recent years, the income provided by agriculture has remained relatively stable. An additional source of income has resulted from the rapidly expanding use of the area for recreation. The most favorable surface transportation route from the Central Valley in California to communities in Oregon and the northwest passes through the project area and within one mile of the project boundary.

Lumbering

Prior to settlement of the Mt. Shasta City--Dunsmuir area by the white man, the southern slopes of Mt. Shasta and the surrounding territory were covered by virgin groves of pine and fir. Subsequent decades of lumbering and destructive forest fires have reduced the amount of harvestable timber available and left many areas unproductive.

Logging, milling, and transportation of lumber supported the early economy of the area, but the modern practice of hauling logs great distances by truck and rail has resulted in a reduction of local milling and manufacturing. The dwindling of virgin timber resources and the slow recovery brought by reforestation practices may result in further decline of the local lumber industry. However, the demand for forest products has remained high during recent years and the lumber industry continues to provide a major source of income for the area.

Agriculture

The extent of irrigated and irrigable lands within the project area is very limited. Downstream from the Box Canyon Project the canyon is very

Looking northwest (from 2 miles north of Dunsmuir). (1) Mt. Eddy (9,025 ft). (2) Black Butte (6,325 ft). (3) Proposed Box Canyon Reservoir site. Most of nonforested area would be covered by reservoir. (4) Private airstrip under construction. (5) Mt. Shasta City. (6) U.S. Highway 99, now improved to interstate standards and designated as Interstate 5. (7) State Highway 89. (8) Sacramento River, flowing toward bottom of photograph. (9) Southern Pacific Railroad. (10) Mott Airport, operated by City of Dunsmuir.

narrow and there is no land suitable for agriculture. The Strawberry Valley area along Wagon Creek and west of Mt. Shasta contains the only land suitable for agriculture near the Box Canyon Project. Most of this land is presently developed and provided with irrigation water from nearby creeks and springs.

Transportation

The Box Canyon Project area is located within 1 mile of Interstate Route 5 (U.S. Highway 99), State Route 89, and the main route of the Southern Pacific Railroad. In addition to its importance to the lumber industry, the Southern Pacific Railroad, with switchyards and track maintenance shops located in Dunsmuir, contributes significantly to the economic life of the project area. Prior to the exclusive use of diesel locomotives on this line, large repair and overhaul shops for steam locomotives were located in Dunsmuir. Because service for diesel equipment is now provided elsewhere, the railroad has reduced its repair shops in Dunsmuir to a minimum. Following this reduction in the early 1950's, the area felt the impact of the payroll loss. In the ensuing years economic stability has been regained, and continued employment at the present level is expected.

Travel time to the Box Canyon area from Redding has been cut almost in half during the past decade because of the improvement of U. S. Highway 99 to interstate standards. This highway branches at Weed with U. S. Highway 99 (Interstate 5) continuing north into Oregon by way of Medford, and U. S. Highway 97 turning northeast to Klamath Falls. The project area is connected to areas further east in California by State Route 89, which intersects State Route 299 near Burney. This highway has also recently been improved, especially in the area between McCloud and Mt. Shasta City. The highway transportation system therefore provides adequate and rapid access to the Box Canyon area from the north, the south, and the east. This entire system is heavily used by vacationers during the spring, summer, and fall months.

Mott airport, operated by the City of Dunsmuir, is located only 3 miles south of the project area along U. S. Highway 99. The surfaced landing strip is open to the public and is adequate for light private planes.

Another landing strip is being constructed within one-half mile of the damsite. This 3,500-foot strip will also be open for public use and is within walking distance of the project recreation area.

Recreation

Siskiyou County, as well as much of the rest of Northern California, is growing in its attractiveness to recreationists. The reason for this growth stems both from the natural attributes of the locality and from the population surge in other portions of the State.

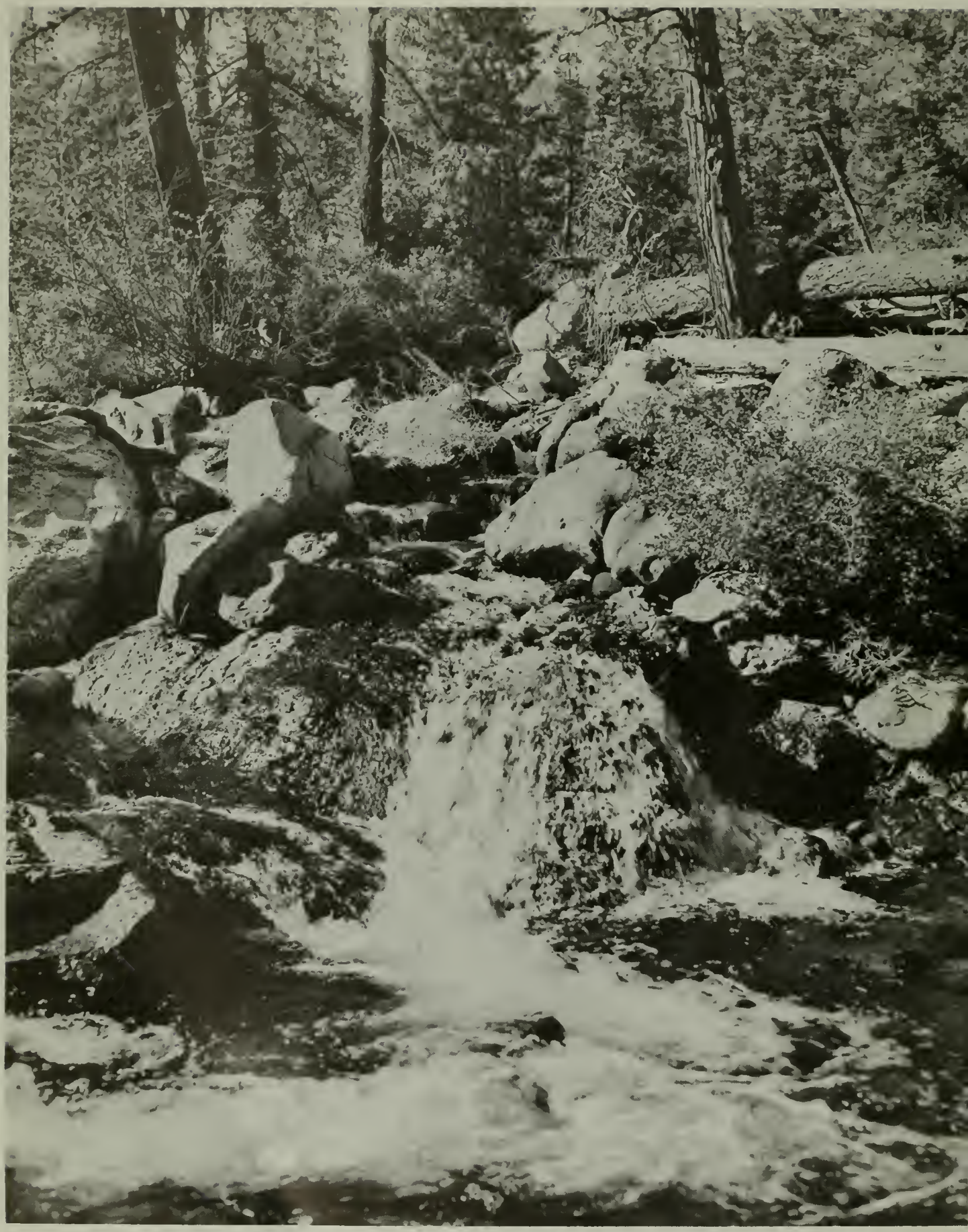
The area around Mt. Shasta is especially attractive to recreationists since the forests and mountains, coupled with the pleasant climate and sparse population, provide the setting that recreationists seek. Mt. Shasta itself is an outstanding attraction. The 14,162-foot peak dominates the entire project area. For much of the year snow covers that portion of the peak above 8,000 feet and several glaciers cling year-round to the mountain. The area around the base of the mountain is noted for its excellent fish and game habitat. The McCloud and Sacramento Rivers above Shasta Lake are noted for their excellent trout fishing.

To the west of the project area nearly all of the land lies within the Shasta National Forest. Within this area, at elevations from 5,500 to 7,000 feet, are many small mountain lakes located in the Eddy Mountains at the headwaters of the Sacramento River. Rainbow, eastern brook, and brown trout inhabit the lakes and streams. The entire area from the Box Canyon damsite to Mt. Eddy is presently used for fishing and hunting.

Despite easy access to the project area, little has been done until recent years toward organizing the recreational opportunities of the area which have long been recognized as among the best in Northern California. In 1958, the completion of the Mt. Shasta Ski Bowl, chairlift and lodge initiated a large-scale attempt to popularize the area for winter sports. Heavy snowpacks that sometimes reach 200 inches on the slopes of Mt. Shasta long have suggested this possibility. The ski season normally would be long, beginning in late November and continuing through June. Although the Ski Bowl operation was plagued by light snowfall seasons and financial difficulties during the first years of operation, retail sales in Mt. Shasta City are reported to have increased considerably since the Ski Bowl has been in operation.

Most of the residents of the project area believe that a reservoir at Box Canyon would provide additional attractions to recreationists, especially fishermen and campers, and would contribute toward the well-rounded, year-round recreational development they desire in their area. The project would supplement the present economy of the area and provide an impetus for further recreational development in Siskiyou County.

"The McCloud and Sacramento Rivers above Shasta Lake are noted for their excellent trout fishing . . . . Rainbow, eastern brook, and brown trout inhabit the lakes and streams".



"Precipitation in the form of rain and snow provides the principal source of water supply to the Sacramento River . . . ."

CHAPTER 3. WATER SUPPLY

Success or failure of water projects often depends on estimates of available water supply. This chapter discusses the water supply, both existing and expected, available to the Box Canyon Reservoir.

Precipitation

Precipitation in the form of rain and snow provides the principal source of water supply to the Sacramento River at the Box Canyon Reservoir site. In the watershed tributary to the reservoir, the precipitation varies from over 60 inches at high elevations on Mt. Shasta to the east and on Mt. Eddy to the west to less than 40 inches at lower elevations near Mt. Shasta City. On the average about 70 percent of the annual precipitation occurs between December 1 and April 1. Plate 1 shows the precipitation pattern on the watershed of Box Canyon Reservoir. The locations of precipitation stations are also shown on Plate 1.

Surface Runoff

Fall and winter rains on the relatively impervious basin area west of Rainbow Ridge provide one increment of runoff, while another increment is provided by the sustained springtime runoff from melting snows in the high mountainous areas. Precipitation on the Mt. Shasta side of the basin does not result immediately in a large amount of surface runoff in the Wagon Creek system since it infiltrates quickly into the extremely porous volcanic soils. However, it does contribute to ground water storage and eventually discharges as part of the sustained summer streamflow. This is evidenced by the large, continuously flowing spring in the Mt. Shasta City park.

The natural flow of the Sacramento River at Box Canyon damsite seldom drops below 40 second-feet during the summer and fall months. This sustained summer flow is regulated both by storage in the Mt. Shasta and Mt. Eddy snowpacks and by ground water basin seepage into the Sacramento River and Wagon Creek stream systems.

Stream Gaging Stations and Records

Records of discharge of the Sacramento River between Shasta Reservoir and Box Canyon damsite are available at four stations. The record of the Trinity River at Lewiston was used to estimate missing years in the Sacramento River records. The stations are listed in Table 1 and locations of the Sacramento River stations are shown on Plate 1.

Impairments

Nearly all exports and diversions of water from the Sacramento River above Shasta Reservoir occur upstream from Box Canyon damsite. Therefore, all four stream gaging stations on the Sacramento River listed in Table 1 have historical recorded discharges which are less, by the amount of upstream impairment, than full natural flow. The total present and expected future impairments are composed of three types of use:

1. Consumptive use of water on irrigated pasture along Wagon Creek.
2. Export of water from North Fork Sacramento River to Shasta Valley for irrigation.
3. Domestic use of water in Mt. Shasta City and outlying rural areas.

Present and estimated future impairments to the streamflow at Box Canyon Reservoir are presented in Table 2. Land use studies indicate that much of the land presently being used for irrigated pasture along Wagon Creek will change to urban and suburban use in the future. These projections indicate that the 1,850 acres of land presently irrigated will be reduced to only 700 acres under irrigation by the year 2020. To establish water supply estimates for project operation studies, the estimated impaired streamflow for the year 2020 was used.

Quantity of Runoff

The surface runoff available for storage, or impaired runoff, at Box Canyon Reservoir was estimated as the natural runoff of the Sacramento River at the damsite, minus upstream impairments expected under year 2020 conditions of development. The term "natural runoff" refers to the streamflow as it would be if unaltered by upstream diversion, storage, import, export, or change in upstream consumptive use caused by development. The term "impaired runoff" refers to the actual streamflow at any given stage of upstream development and, in the case of past flows, constitutes the historical record.

TABLE 1

STREAM GAGING STATIONS USED IN ESTIMATING WATER SUPPLY

Station	Operator	Drainage Area (square miles)	Period of Record
Sacramento River			
Near Mt. Shasta	DWR*	129	May 1959 to date
At Castella	USGS**	257	Oct. 1910 to Sept. 1917 Oct. 1919 to Sept. 1923
At Delta	USGS	427	Oct. 1944 to date
At Antler	USGS	461	Oct. 1910 to Dec. 1911 May 1919 to Sept. 1941
Trinity River			
At Lewiston	USGS	727	Oct. 1908 to date

* Department of Water Resources
** United States Geological Survey

TABLE 2

PRESENT AND ESTIMATED FUTURE IMPAIRMENTS
UPSTREAM FROM BOX CANYON DAMSITE

Year	Export to Shasta Valley (acre-feet)	Agricultural Use From Wagon Creek		Urban and Suburban Domestic Use (acre-feet)	Annual Total Impairments (acre-feet)
		Irrigated Acres	Consumptive Use (acre-feet)		
1965	1,600	1,850	4,700	900	7,200
2020	1,600	700	1,700	6,200	9,500

Monthly Distribution of Year 2020 Impairments
(acre-feet)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
200	260	270	500	970	1,330	2,060	1,870	920	540	360	220	9,500

Runoff was estimated for the period 1914-15 through 1963-64 because this period contains the greatest number of years of recorded flow of the Sacramento River near the damsite and because it includes both wet and dry periods. It was assumed that natural runoff at the site during this period may be taken statistically to represent any 50-year period following project construction.

Although no historical record exists for natural runoff at the damsite, such runoff is assumed to be about 96 percent of the natural runoff at the Mt. Shasta stream gaging station because the drainage area above the damsite is in that proportion. The Mt. Shasta stream gaging station on the Sacramento River is located 1-1/2 miles downstream from the damsite and has provided a continuous record of runoff from May 1959 to date. Natural runoff occurring at the stream gaging site during the remaining years of the 50-year period (1914-15 through 1963-64) was estimated by correlation with the streamflow records of the Sacramento River at the Delta station. Data for missing years in the Delta record were estimated from recorded flow of the Sacramento River at Antler and the Trinity River at Lewiston. All estimates of annual runoff were made on the basis of estimated natural runoff. Figure 1 shows the relationship between annual precipitation and estimated natural runoff of the Sacramento River at the Mt. Shasta gaging station.

Estimates of monthly impaired runoff at the Box Canyon damsite over the last 50 years with upstream impairments at the year 2020 level are presented in Table 3. The total runoff and the annual and monthly distribution shown were assumed to be representative of any future 50-year period. Under the imposed conditions, the average annual impaired runoff available for storage at Box Canyon would be 160,000 acre-feet.

The impaired runoff estimates at the damsite for the period 1914-15 through 1963-64 were made by:

1. Estimating the annual natural runoff at the damsite from the natural runoff at Delta.
2. Distributing the natural runoff at the damsite estimated for each year on a monthly basis by the "percent deviation"

method.[1/] Monthly flow records and estimates at the Delta station were used in this method to estimate flow at the damsite.

3. Subtracting the estimated year 2020 impairments to monthly runoff at the damsite, as presented in Table 2, from the computed natural runoff at the damsite.

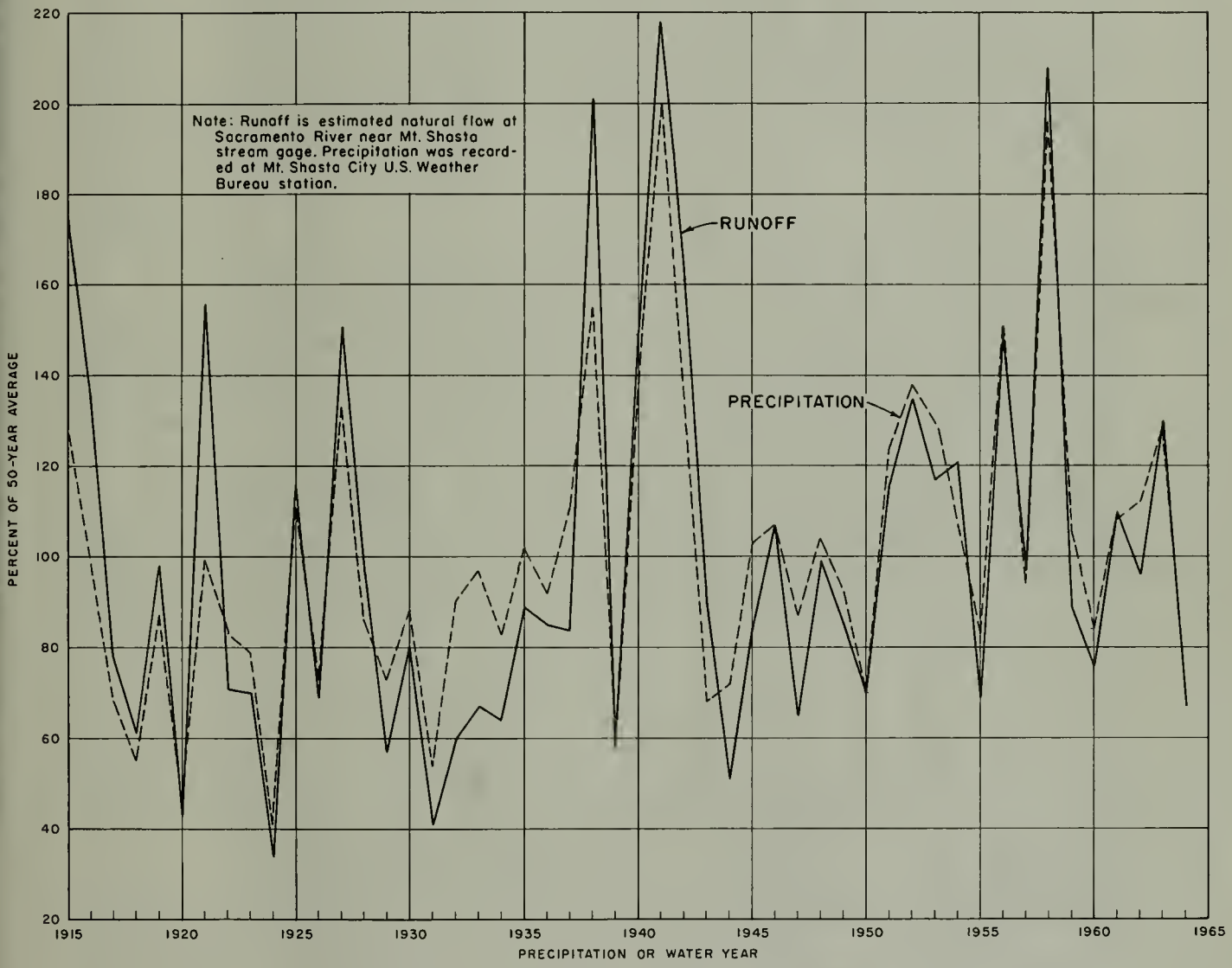


Figure I. COMPARISON OF ANNUAL PRECIPITATION AT MT. SHASTA CITY AND RUNOFF OF SACRAMENTO RIVER NEAR MT. SHASTA

1/ This method is based on the premise that two streams, or in this case different drainage areas on the same stream, which have similar runoff characteristics have the same ratio of runoff in any given month to the mean monthly runoff.

TABLE 3

ESTIMATED FUTURE IMPAIRED RUNOFF OF SACRAMENTO RIVER AT BOX CANYON DAMSITE
(In thousands of acre-feet)

Season	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Total
1914-15	7.1	7.4	9.2	23.5	54.8	33.6	57.4	45.2	31.5	9.3	4.7	4.0	287.7
16	5.1	6.6	16.3	27.4	34.8	30.4	31.9	34.5	18.2	7.6	3.6	3.3	219.7
17	3.8	4.6	6.3	5.8	12.7	9.5	30.8	30.1	12.2	3.4	1.7	1.8	122.7
18	3.5	4.6	5.6	4.8	7.0	14.7	19.9	17.5	9.2	3.1	1.7	2.4	94.0
19	5.6	5.9	5.7	13.0	23.4	21.5	31.6	28.7	12.0	4.4	2.4	2.6	156.8
1919-20	3.1	3.3	4.2	3.5	2.9	6.1	15.5	14.0	7.4	2.3	1.0	1.4	64.7
21	4.2	26.1	28.3	38.3	25.8	28.9	31.5	40.8	19.6	6.2	3.0	3.0	255.7
22	2.9	3.7	6.4	5.0	10.4	10.5	23.9	30.5	11.9	2.9	1.2	1.5	110.8
23	4.2	5.9	10.2	10.6	6.1	6.5	26.0	18.9	12.1	4.0	1.7	2.1	108.3
24	3.1	3.5	3.4	3.9	6.0	3.6	6.3	9.3	6.3	1.9	0.7	1.2	49.2
1924-25	3.8	8.8	7.9	8.1	40.6	14.0	42.6	35.4	16.4	4.4	2.3	2.6	186.9
26	3.4	4.6	5.2	6.6	22.5	8.3	24.0	18.5	9.1	3.0	1.3	1.6	108.1
27	3.7	17.6	20.8	21.3	41.8	24.1	50.3	39.4	17.2	5.2	2.4	2.7	246.5
28	3.6	11.5	8.7	11.4	15.3	25.5	35.7	24.1	10.9	3.9	1.7	2.2	154.5
29	3.3	5.8	5.8	5.6	9.0	7.4	15.1	18.8	10.4	2.9	1.1	1.7	86.9
1929-30	3.3	4.0	16.6	11.1	13.5	18.9	18.1	23.3	10.5	3.3	1.4	2.2	126.2
31	3.5	4.0	3.6	7.4	5.4	7.2	8.6	10.3	6.0	1.5	0.9	1.4	59.8
32	2.9	3.2	11.1	7.7	5.3	12.1	14.7	24.4	8.2	1.6	0.9	1.3	93.4
33	3.1	3.6	4.0	6.4	4.7	19.0	20.2	26.3	11.6	2.4	1.2	1.6	104.1
34	3.6	4.0	9.4	13.7	12.3	11.3	15.1	16.8	8.0	2.3	1.3	1.7	99.5
1934-35	2.6	7.3	5.3	13.1	8.7	13.0	48.1	31.4	9.4	2.0	0.8	1.2	142.9
36	3.5	3.5	4.4	25.0	25.7	12.4	21.5	21.5	12.4	2.8	1.1	1.6	135.4
37	3.1	3.2	3.4	3.9	9.6	23.0	35.4	32.8	13.1	2.8	1.0	1.6	132.9
38	4.5	23.5	33.4	16.3	41.3	56.1	57.8	64.1	22.1	5.9	2.9	2.8	330.7
39	5.5	6.1	7.8	7.1	6.0	12.7	14.1	15.7	7.7	2.6	1.6	2.1	89.0
1939-40	4.0	4.4	8.4	33.1	44.9	42.5	52.6	31.5	12.9	4.3	2.4	2.9	243.9
41	5.5	7.0	36.8	49.0	41.3	41.6	75.0	62.6	25.6	7.7	4.1	4.0	360.2
42	6.5	6.5	30.4	31.6	42.2	13.7	45.9	51.7	24.3	6.4	3.4	3.3	265.9
43	4.1	5.4	8.3	22.6	13.0	19.1	25.1	25.2	12.6	3.8	1.7	2.0	142.9
44	4.0	4.2	3.8	5.0	8.2	9.2	11.8	17.0	9.5	2.3	1.0	1.5	77.5
1944-45	1.9	7.4	13.9	9.2	22.7	10.0	20.8	28.3	11.1	3.0	1.6	1.8	131.7
46	7.3	15.1	37.7	20.1	7.5	12.6	26.7	29.0	9.5	3.0	1.7	2.0	172.2
47	2.9	6.7	6.1	3.4	9.4	16.7	16.7	10.8	20.9	3.5	1.9	1.9	100.9
48	7.0	4.0	3.2	25.3	3.8	7.5	35.9	39.1	23.5	5.0	2.3	2.5	159.1
49	3.6	3.8	3.8	3.1	8.1	33.9	35.4	29.3	9.1	2.5	1.6	1.9	136.1
1949-50	2.6	2.7	2.5	9.2	11.8	14.2	28.1	23.7	8.5	2.0	1.3	2.0	108.6
51	27.6	19.2	28.7	15.5	22.4	12.4	19.1	28.0	7.8	2.7	1.8	2.0	187.2
52	3.3	10.8	27.2	13.0	22.9	19.9	42.9	49.4	18.3	6.0	2.7	2.6	219.0
53	2.8	2.8	11.6	45.2	10.4	16.4	27.6	35.5	24.3	6.8	3.1	2.7	189.2
54	4.2	14.3	8.3	22.8	29.0	22.5	45.1	30.2	9.8	3.7	3.3	3.0	196.2
1954-55	3.9	10.0	15.0	6.0	5.4	6.6	17.0	29.9	8.1	2.5	1.3	1.9	107.6
56	2.4	4.9	47.6	46.3	23.1	17.8	29.4	43.4	18.4	4.9	2.7	2.7	243.6
57	3.7	3.1	2.6	4.4	23.7	20.6	21.4	51.1	12.1	3.5	1.9	7.0	155.1
58	19.8	10.3	17.5	24.2	76.0	33.1	53.1	63.9	31.0	8.4	4.2	3.7	345.2
59	4.0	3.3	3.4	34.5	19.2	16.6	24.4	20.3	7.9	2.6	1.9	3.0	141.1
1959-60	3.3	3.3	4.2	6.2	15.2	23.9	19.9	23.8	12.3	3.2	2.4	2.5	120.2
61	3.3	5.9	15.6	10.3	28.4	15.9	27.0	39.3	21.2	4.1	2.6	2.7	176.3
62	3.3	5.3	8.3	6.8	17.4	11.5	45.1	31.4	14.2	3.8	2.7	2.6	152.4
63	18.6	12.4	24.9	9.7	39.8	13.2	35.1	38.0	9.9	4.3	2.6	2.6	211.1
1963-64	5.3	15.3	9.1	10.4	8.9	10.5	16.6	13.7	8.7	3.3	2.0	2.7	106.5
Average	5.0	7.4	12.4	15.3	20.0	17.8	29.9	30.4	13.5	3.9	2.0	2.4	160.0

NOTE: Impairments to runoff are estimated for year 2020. The impairments used are shown in Table 2.

Water Quality

Success of a water project depends on the quality of water as well as on the quantity of water. The project can be useful only if the water quality is satisfactory for the beneficial uses for which the water is intended. Since recreation and fishery enhancement are the primary purposes of the Box Canyon Project, water quality studies were centered around the requirements for these purposes.

Reservoir

Many aspects of water quality affect the ability of a reservoir to provide a suitable environment for fish production and water-oriented recreation activities. The water quality aspects believed to be most important to recreation and fisheries and subsequently investigated during this study were (1) mineral content, (2) turbidity, (3) temperature, and (4) aquatic biology.

Mineral Content. Water from all major tributaries to Box Canyon Reservoir, including the Sacramento River, Wagon Creek, Cold Creek, Big Springs Creek, and Scott Camp Creek, was sampled and analyzed for mineral content during this study. Table 4 presents the results of these analyses.

TABLE 4

MINERAL CONTENT OF STREAMS TRIBUTARY TO BOX CANYON RESERVOIR

	Quality Characteristics			
	Electrical Conductivity 1/ (micromhos)	Hardness 2/ (parts per million)	Boron (parts per million)	Sodium (percent of base constituents)
High Value	195	95	0.07	35
Low Value	36	38	0.0	4
Number of Analyses	26	6	5	6

1/ Electrical conductivity is used as a measure of the total dissolved mineral in a water.

2/ Expressed as $CaCO_3$

The mineral content shown in these analyses is within the recommended limits for irrigation and drinking water. Although there are few standards for judging the quality of water required to maintain trout in California mountain streams, trout now live and propagate in all tributaries above the reservoir site. Based on these observations and analyses, it was concluded that the mineral content of the water flowing into Box Canyon Reservoir would be satisfactory for all proposed project purposes.

Using the proposed plan of reservoir operation discussed in Chapter 5, mineral concentration in the reservoir was studied under project conditions. The study period selected was August 1922 through November 1926 since the most critical period of low reservoir volumes occurred during that part of the reservoir operation study (1915-1964). It was estimated that the electrical conductivity of the reservoir waters during this 52-month period would have a high value of 157 micromhos, a low value of 90 micromhos, and a medium value of 119 micromhos. These values indicate that the water impounded in Box Canyon Reservoir would be of excellent mineral quality for all proposed uses, even under the most adverse dry-year conditions.

Turbidity. Turbidity, or cloudiness of water, is due to suspended matter which obstructs the passage of light. In a recreation reservoir, turbidity may be objectionable because of the appearance of the water and because of the effect it may have on biologic growth such as phytoplankton.

Two physical factors which may significantly influence the level of turbidity in a stream are rock and soil types and vegetative cover. The rock and soil types found in the watershed tributary to Box Canyon Reservoir would contribute only limited amounts of clay which produces turbidity. The present vegetative cover in the undeveloped portion of the watershed is adequate to keep turbidity levels low. In the developed portion of the watershed agricultural and urban activities apparently have not caused a turbidity problem in the streams and should cause none in the future.

Temperature. Water temperatures in the reservoir will also have an effect on recreation and fisheries enhancement. Certain water temperature ranges are desirable for water contact sports, aquatic growth for fish food, and water released for the downstream fishery.

Because the reservoir will be deep and because the summer and winter air temperatures differ widely, it is believed that thermal stratification will take place during the summer. An examination of the thermal stratification which takes place in other lakes and reservoirs at similar latitude, elevation, and depth indicates that a thermocline (zone of greatest temperature gradient) will develop in the proposed reservoir each year somewhere in the depth range of 20 to 55 feet.

During most of the recreation season the zone above the thermocline would probably have a maximum temperature no greater than 75°F. and a minimum temperature of about 55°F. The temperature in the zone below the thermocline (from 55 feet to the bottom of the reservoir) would range between 40°F. and 55°F. during most of the stratification period.

It is concluded that the reservoir surface temperature would be satisfactory for water contact sports and that the temperature in the lower portion of the reservoir will be cold enough to provide water of suitable temperature to release for the downstream fishery.

Aquatic Biology. Any body of fresh water will support some forms of plant or animal life. The particular species which are present and numbers of individual organisms which develop are determined by environmental conditions. Some of the more significant conditions and those considered in evaluating possible aquatic growth at Box Canyon are (1) nearness and degree of physical continuity with other waters, (2) exposure to solar energy, (3) water temperatures and character of thermal stratification, (4) availability of nutrients and certain essential trace materials, and (5) water depths and length of shoreline.

Studies made at Dwinnell Reservoir on the Shasta River and Copco Lake on the Klamath River indicate that an algae problem could develop in the Box Canyon Reservoir. However, the problem area would probably be confined to the Wagon Creek arm of the reservoir since Wagon Creek will contribute more nutrients (phosphates and nitrates) required for algae growth than will the other creeks tributary to the reservoir. Table 5 presents the range of nutrients found in samples taken from streams tributary to Box Canyon Reservoir.

TABLE 5

CONCENTRATION OF PHOSPHATES AND NITRATES
IN STREAMS TRIBUTARY TO BOX CANYON RESERVOIR

Source	Date	Estimated streamflow (second-feet)	Total Phosphate (parts per million)	Nitrate (parts per million)
Sacramento River (above Scott Camp Creek)	9-4-59	7	*	0.0
	5-3-60	60	*	0.2
	9-29-60	13	*	0.6
	5-8-61	300	*	0.5
	10-28-64	20-25	0.02	1.2
Scott Camp Creek (above Castle Lake Creek)	9-23-64	1-2	*	0.0
Scott Camp Creek (below Castle Lake Creek)	8-13-64	2	0.01	0.1
	10-28-64	12	0.08	1.4
Sacramento River (between Scott Camp Creek and Wagon Creek)	8-13-64	15	0.03	0.4
Big Springs Creek at mouth	10-28-64	10	0.60	1.7
Cold Creek at mouth	10-28-64	22	0.59	1.5
	1-6-65	100	0.23	2.7
Wagon Creek below Cold Creek	8-13-64	20	0.29	0.4
	10-28-64	50	0.41	1.6
Sacramento River below Wagon Creek	8-13-64	35	0.24	0.9

* No phosphate analysis made on sample.

The location of the Wagon Creek arm of the reservoir is such that if algae growth did develop, the high-nutrient creek water could be diverted to a point below the dam and out of the reservoir during the summer. Another possible solution would be to divert this water around the reservoir edge and into the main body of the reservoir near the center of Section 29. This would allow more complete mixing of the nutrient-laden waters within the main body of water. This diversion canal quite possibly could also be used as an artificial spawning channel for trout.

This Wagon Creek arm of the reservoir should be closely watched during the initial years of the project operation and if a problem does develop remedial action such as that suggested in the previous paragraphs should be taken.

Water Supply for Recreation Development

The proposed water supply for the recreation area would be diverted from Scott Camp Creek about 1 mile upstream from its confluence with Castle Lake Creek. A sample of water collected near the diversion point on October 23, 1964, was analyzed for mineral content. The analysis indicates that both hardness and total dissolved solids are well within domestic water limits but that the water probably would be slightly corrosive.

It is concluded that with minimum filtering and proper chlorination the water diverted from Scott Camp Creek would be suitable for domestic use at the recreation facilities.

Water Rights

To legally store water in Box Canyon Reservoir, a permit must be obtained from the State Water Rights Board. Since no water rights application has been made for the Box Canyon Project, the local agency accepting responsibility for the project should file an application at the earliest practical date.

Existing water rights both upstream and downstream from the proposed storage site will be considered by the State Water Rights Board before a permit is granted.

Existing Upstream Water Rights

Upstream from the proposed Box Canyon Reservoir there are many farms and rural homes which use water from the Sacramento River and its tributaries. Most of these users are exercising riparian rights or appropriative rights initiated prior to 1914. Only a few of the diversions are made under licenses or permits issued by the State Water Rights Board.

Six licenses and three permits to divert and/or store water have been issued by the State Water Rights Board in this area. The total of all diversions allowed by these licenses and permits is 20 cubic feet per second and the total storage allowed is 485 acre-feet.

Storage of surplus water in Box Canyon Reservoir would not interfere with any upstream water rights.

Existing Downstream Water Rights

Between the Box Canyon damsite and Shasta Reservoir there are many riparian owners, but there is very little storage, diversion, or use of Sacramento River water. Applications to permit storage of water in Shasta Reservoir were filed in 1927 by the State of California and were assigned to the Bureau of Reclamation in 1938. Included in the assignment to the Bureau of Reclamation is a clause reserving water to upstream counties of origin for their future water requirements. This reservation would permit the depletion of inflow to Shasta Reservoir by 700,000 acre-feet in one year, but not to exceed 4,500,000 acre-feet in any 10-year period.

Future reservoirs, such as the Bureau of Reclamation's proposed Allen Camp Reservoir on the Pit River and the McCloud River Power Development presently being built by Pacific Gas and Electric Company, would increase storage above Shasta Reservoir by only 245,000 acre-feet. Therefore, these reservoirs, plus Box Canyon Reservoir with a storage capacity of 26,000 acre-feet, would increase the upstream storage far less than the allowable depletion to Shasta Reservoir inflow.

CHAPTER 4. PROJECT FEATURES AND COSTS

Before physical project features can be designed and cost estimates prepared, the project purposes must be selected and the proper size and staging of development determined. This phase of the study is called project formulation. This chapter begins with a discussion of how the Box Canyon Project was formulated. Selection of the actual damsite is then mentioned briefly, and a semidetailed discussion of geology as it pertains to the reservoir, the damsite, and the construction materials borrow areas is presented. This information was used in designing the project structures.

The project structures are discussed in the "Physical Features and Costs" section, which is the major portion of this chapter. The physical features proposed for the Box Canyon Project were designed on the basis of engineering and geologic studies conducted to determine the most economical means of satisfying the project purposes. Estimates of project costs were based on these designs.

The chapter closes with comments on the preservation of wildlife and a summary of all project costs.

Project Formulation

For a water development project to be properly formulated, it must maximize the net economic returns and the human satisfactions from the economic resources used in the project. In a multiple-purpose project, such as that considered at Box Canyon, each separable purpose must provide benefits at least equal to the cost of including that purpose.

Selection of Project Purposes

During the reconnaissance study of the Mt. Shasta City--Dunsmuir area, reported on in Department Bulletin No. 100, several possible project purposes were considered for the Box Canyon Project. The purposes considered were (1) recreation, (2) fisheries enhancement, (3) flood control, (4) hydroelectric power generation, (5) water conservation for irrigation, municipal,

and industrial uses, and (6) provision of a supplemental water supply to the State Water Facilities. From that study it was concluded that the only purposes which should be included in the project were recreation and fisheries enhancement.

During this feasibility study all of the above purposes were reconsidered. Additional information on flood control and economic changes which have taken place since the last study was completed were considered. As a result of the October 1962 and December 1964 floods important hydrologic and flood damage data were collected. Analysis of this new information shows that a small amount of flood storage reservation in the reservoir would be justified and that flood control can be included as a purpose of the project. Still not justified are the purposes of hydroelectric power generation, water conservation for irrigation, municipal, and industrial uses.

Therefore, the purposes justified for inclusion in the project are recreation, fisheries enhancement, and flood control. The project was formulated to provide the maximum net benefits from the combination of these three purposes.

Project Sizing

One of the difficult tasks during the project formulation phase of any water project development study is the determination of the scale and scope of development. This is commonly referred to as 'project sizing'. The optimum scale of development is attained when the net project benefits are maximized; that is, when the excess of benefits over costs is at a maximum. Net project benefits are maximized when the scale of development is extended to the point where the benefits added by the last increment of scale or scope are equal to the cost of adding that increment.

Sizing of the Box Canyon Project was doubly difficult since the change in recreation benefits from small changes in the scale of development is extremely difficult to estimate. Midway through this study it was required that a dam and reservoir size be selected so that designs and cost estimates could be prepared for the optimum size. Project costs and benefits were estimated and compared for four reservoir normal water surface elevations,

3,170', 3,180', 3,190', and 3,200', USGS datum. Although final benefits and costs were not available at that time, any significant changes in benefits or costs were considered relative throughout the range of development being studied.

The cost estimates were based on project costs estimated for Bulletin No. 100 updated to 1965 cost levels, and revised to account for increased knowledge of subsurface geologic conditions at the damsite. Benefits were also based on Bulletin No. 100 estimates of use tempered for changes in the scale of development. Changes in the amount of project use were generally based on the judgment of the recreation planner regarding the compatibility of the land and water surfaces, and the fisheries biologist regarding productivity of the reservoir fishery at different water surface elevations.

Results of the project sizing study showed that the net project benefits would be maximized with a reservoir having a storage capacity of 26,000 acre-feet and a surface area of 430 acres. This size was therefore selected for final feasibility determinations, and is the size finally selected.

Selection of Damsite

Two damsites were considered in preliminary planning during the reconnaissance study. The upper damsite is located in Section 29 near the entrance to Box Canyon. The lower damsite is located in Section 33 near the lower end of the canyon. It would be physically possible to construct a larger dam which could impound as much as 88,000 acre-feet of water at the lower site. However, the streambed elevation at the lower site is about 100 feet lower than at the upper site. Consequently, about four times as much dam embankment would be required at the lower site as at the upper site to impound a similar quantity of water. Since there was no need for a large amount of reservoir storage for recreation and fisheries enhancement, and since inclusion of large flood control storage was unwarranted, the upper site was selected as the most economical site. All further reference to the Box Canyon damsite therefore will be to the site located about 1,000 feet downstream from the entrance to Box Canyon in the SE$\frac{1}{4}$, Section 29, T40N, R4W, Mt. Diablo Base and Meridian. The damsite location is shown on the map opposite the first page of Chapter 2 and in greater detail on Plates 3 and 4.

Geology

One of the major objectives of this investigation was to obtain reliable information about the subsurface geology at the Box Canyon damsite and to explore and test materials to determine their suitability for dam embankment. The damsite geology investigation was accomplished by core drilling and water testing eight holes in the foundation rock. Total footage of all diamond drill core holes was 1,202 feet. In addition, an 8-inch-diameter, 200-foot-deep, gravel-packed well was constructed high on the left abutment to obtain data on ground water and permeability of the abutment material. Locations of all drill holes are shown on Plate 3, "Box Canyon Dam on Sacramento River."

An extensive seismic survey was also conducted at the damsite to aid in identifying contacts between the different types of rock in the dam foundation.

A survey to locate and identify suitable borrow materials was also completed. Four locations within 1 mile of the damsite were explored and samples were taken for laboratory analysis and testing. A backhoe and auger drill were used in borrow exploration. In all, 50 backhoe trenches and 32 auger holes were dug and sampled. The backhoe trenches ranged from 4 to 14 feet deep, and the auger holes ranged between 17 and 25 feet deep.

A detailed office report titled "Engineering Geology of Box Canyon Damsite, January 1965", was prepared and a limited number of copies are available in the files of the Department.

Regional Geology

A study of regional geology provided the information needed to analyze the water supply and to appraise the geologic suitability of the Box Canyon Dam and Reservoir site. Volcanic activity played the major role in geologic development of this area.

The Box Canyon Dam site is located near the geologic boundary between the Klamath Mountains and the Cascade Range. Characteristic rock formations of both mountain ranges are present nearby.

The Klamath Mountains, lying west of the reservoir area, contain intrusive, sedimentary, and volcanic rocks. The Cascade Range contains volcanic rocks which are divided into two units: the Western Cascade series and the High Cascade series. The Western Cascade series, an older outcropping, lies to the west of the peaks of the Cascade Range and extends north from Mt. Shasta into Oregon. The High Cascade series, a younger unit, includes both Mt. Shasta and Mt. Lassen.

The erosion which preceded Western Cascade volcanism created a valley between Rainbow Ridge and Ney Springs Creek. The lava flows that contributed to the Western Cascade series covered any sediments that may have been deposited in this valley. These lava flows outcrop in several places to the west of Box Canyon and in the reservoir area. They form the walls of Box Canyon and apparently terminate a short distance east of the canyon. A lava flow which ages ago blocked the canyon at Mott, several miles below the damsite, formed a lake that extended around the west end of Box Canyon and into the proposed reservoir area. From the proposed reservoir area to Mott, the Sacramento River has exposed the sediments which indicate the past presence of this lake.

Seismicity is the tendency or relative probability of an area to experience earthquakes. The determination of seismic activity for any area is based on knowledge of the recorded earthquake history. The earthquake history of the Box Canyon area, including the Klamath Mountains to the west and the Cascade Range to the east, indicates a relatively low seismic activity. No shocks greater than magnitude 4 on the Richter scale are known to have occurred within a 40-mile radius of the damsite. In general, earthquakes with magnitudes of 1 through 4 are slight shocks resulting in little or no damage to structures founded on hard rock.

Reservoir Geology

In relatively recent times the entire valley which would contain the reservoir was filled with a variety of sediments related to the glacial activity of Mt. Shasta. Erosion has since carried away most of the sediments but terraces around the perimeter of the reservoir area indicate the past presence of sedimentary material ranging from very coarse, bouldery sand deposits to very fine lake deposits.

The top photograph (looking downstream) shows the centerline of Box Canyon Dam, the present Mt. Shasta City sewer farm and dump which will be relocated to the cleared area at top right, and the Castle Lake road at lower right.

The bottom photograph was taken looking downstream into the damsite. Note the nearly vertical canyon walls.

Only one area in the reservoir should present any problem of leakage. This is along the Wagon Creek arm of the reservoir where about 90 feet of gravelly sand and silt overlie a section of the lake deposits. Movement of water from the reservoir through the gravelly sand deposits could cause piping of fine-grained material and seriously affect the stability of the left abutment of the dam.

To determine the extent of the problem and aid in finding a solution, two permeability tests were conducted in this area. One conducted in the gravelly sand in 1960 indicated a permeability rate of at least 5 feet per day. During this study a permeability estimate of the underlying lake sediments was made by pump-testing exploration hole LA-4 (see Plate 3 for location of test holes). Results of the pump test indicated that the permeability of the lake sediments is about 1.0 foot per day. A more thorough discussion of the permeability testing is presented in the Engineering Geology Office Report. Results of these tests indicate that measures should be taken to prevent excessive leakage and possible piping of materials through the left abutment.

Silting in the reservoir is not expected to be a major problem. The geologic structure of the drainage area is such that most of the materials carried by the stream are sand, gravel, and boulders. These would be deposited at the upstream end of the reservoir. The load of suspended material which would be deposited over the downstream portion of the reservoir should be small.

Damsite Geology

The damsite lies near the entrance to the steep-walled canyon of the Sacramento River which cuts through a jointed mass of hard, dense, volcanic rock of andesitic composition. Unconsolidated sediments of glacial origin overlie the volcanic rock on the left abutment. Beneath these glacial deposits are a series of stratified and partially consolidated silts, sands, and clays which were deposited in an ancient lake. Above the rock rim on the right abutment is a low density tuff which is in a highly weathered condition near the ground surface. On Plate 3 a section near the dam axis shows the contacts of the various geologic strata. The photograph on the opposite page shows the steep-walled canyon at the damsite.

Right Abutment. The portion of the right abutment below elevation 3,150 feet is a cliff of volcanic rock, nearly vertical and at places overhanging. Above elevation 3,150 feet the volcanic rock is covered with a residual soil derived from the chemical weathering of a volcanic tuff and tuff breccia which lies directly over the hard, gray volcanic rock.

Three diamond-drill core holes were drilled in this abutment. Locations of the holes are shown on Plate 3. Information gained from drilling these holes was used to determine the contact between the various geologic strata and to estimate the amount of grout required to seal off the abutment. Fractures are common in the andesitic rock, and water pressure tests conducted at the drill holes indicate that the grout take would be high in the upper portion of the abutment and decrease deeper in the abutment.

Stripping of soil cover will vary from less than 1 foot at the canyon rim to about 15 feet at the dam crest elevation. This will expose fresh andesite near the canyon rim and firm but weathered volcanic tuff suitable as a base for placing the small volume of fill required at higher elevations.

Channel Section. At streambed the channel is about 50 feet wide and bounded by nearly vertical rock walls. Fresh, hard bedrock is exposed throughout much of the channel section. Stripping will consist of only a minor amount of sand, gravel, and boulder removal with minor shaping of the bedrock.

Exploration in the channel section revealed that the andesitic volcanic rock exposed in the floor and canyon walls extends to a sufficient depth beneath the channel and laterally into the abutments to provide an excellent foundation for a fill-type dam. One diamond drill hole was drilled vertically near the canyon entrance. In that hole the andesitic rock extended from streambed to 80 feet in depth, tuff breccia from 80 to 160 feet, and decomposed granodiorite from about 160 feet to the bottom of the hole at 200 feet.

Two angle holes were drilled into the bases of the abutments. In these holes there was almost total core recovery of fresh, slightly fractured, andesitic volcanic rock. Water pressure tests at these holes indicate that rock generally is moderately fractured and slightly open in the first 30 feet, but that below that depth any fractures and joints are tightly closed.

Left Abutment. The andesitic volcanic rock on the left abutment is exposed from the streambed to about elevation 3,125 feet. A glacial drift material, originating from the slopes of Mt. Shasta and composed of a gravelly sandy silt containing numerous cobbles and large boulders, overlies the volcanic rock. From surface evidence the volcanic rock appears to end a short distance beneath the surface of the abutment where it is replaced by lake deposits and glacial drift. Because of this observation most of the exploration of this abutment was directed to determining the permeability of the glacial- and lake-deposited materials and the surface configuration of the volcanic rock within the abutment. Subsurface investigation has included two seismic surveys, the drilling of two core holes and two auger holes, and construction of a gravel packed well. Detailed logs of the holes and results of testing sampled materials is presented in the Engineering Geology Office Report.

As previously discussed in the section on reservoir geology, a possibility exists that water will leak from the reservoir through the ridge of glacial drift and lake sediments that forms the left abutment of the damsite. This could result in piping of fine-grained materials and subsequent failure of the abutment. Field permeability tests were conducted to explore the extent of this possibility. Results of these tests indicate that the left abutment should receive special treatment to prevent possible piping of materials.

The configuration of the volcanic rock and the contact between the lake and glacial deposits as determined by drilling and seismic methods are shown on Plate 3.

Water pressure tests in hole LA-1 indicated that the rock from 70 to 90 feet below the surface is slightly open and below 90 feet the fractures are closed. Less grout will be required than in the right abutment.

Stripping in the rock wall portion of the canyon will involve only shaping and removal of loose rock. Above the rock canyon rim the amount of stripping will depend upon the selected treatment of the glacial material. However, this material could be easily removed by common excavation and might be salvaged for use in the transition section of the dam.

Spillway. The spillway would be located on the right abutment and would consist of a concrete ogee weir with crest elevation at 3,181 feet and a concrete-lined chute to return the water to the river channel.

One diamond drill hole, RA-2, was drilled near the centerline of the spillway at the weir location. The following tabulation summarizes the rock conditions at the weir as determined from data obtained from RA-2:

Depth (in feet)	Description
0 to 10	Soil underlain by weathered tuff. Excavation by common methods. Slopes stable at 2:1.
10 to 20	Weathered tuff gradually becoming more resistant and firm. Light ripping required in lower portion of zone. Slopes stable at 1:1. Rock at 20 feet probably suitable for placing chute portion of spillway.
20 to 26	Slightly weathered and fractured hard tuff. Light blasting and ripping required. Slopes stable at 1:1 to 1/2:1. Rock probably suitable for weir foundation at 25 feet.
26 and greater	Fresh but fractured tuff at 26 to 33 feet. Hard andesite at 33 feet. Moderately heavy blasting required. Slopes stable at 1/2:1.

These conditions apply uniformly to the central portion of the spillway near the weir. However, in the lower one-third of the spillway chute and the upper one-third of the approach channel, firm rock would be reached at a lesser depth and deep cuts would require more hardrock excavation.

The entire spillway chute should be lined because of the erodible nature of the weathered tuff and highly fractured nature of the fresher rock beneath. A grout cutoff should be provided beneath the weir section to eliminate excessive leakage through the fractured andesite.

Construction Materials

During the period December 1963 to May 1964, an extensive investigation was conducted in four locations within 1 mile of the damsite axis to explore and sample impervious and semipervious construction materials. Borrow area B-2 was explored by drilling 32 auger holes generally to depths of 25 feet. Borrow areas B-1, B-4, B-5, and B-6 were explored with approximately 45 backhoe trenches to a maximum depth of 14 feet. Borrow area B-3 had previously

been explored and adequately sampled in 1960, and no further work was conducted there during this investigation. The location of these borrow areas is shown on Plate 2. Characteristics of borrow areas and properties of construction materials are presented in Table 6. A summary of all borrow exploration appears in Table 2 of the Engineering Geology Office Report; soil test results are summarized in Tables 4 and 5 of the same report.

Impervious Material. Three borrow areas, B-2, B-5, and B-6, were explored and sampled in the search for impervious borrow material. Borrow area B-2 consists of a material which is classified as a plastic silt or a silty sand. It is actually an in-place decomposed volcanic rock which, when augered and prepared for laboratory testing, readily breaks into a granular material. This material can be either silt, sand, or gravel, depending on the extent of decomposition and amount of mechanical breakdown. Although on the basis of particle size the material classifies as silt, the mineralogical classification is clay. To determine the type of clay mineral present, differential thermal analyses were conducted. All samples tested indicated that the clay mineral is halloysite. Halloysite is a member of the kaolinite group of clay minerals. Although this clay is not expansive, it possesses rather unusual engineering properties such as low compacted density and high water content, and variation of plasticity with moisture content. These unusual properties were confirmed during laboratory testing of the material. A detailed discussion of laboratory testing results is presented in the Engineering Geology Office Report.

Results of the laboratory tests indicate that the material will require drying prior to placing, but excessive drying may result in loss of plasticity. Nearly 2 million cubic yards of this material are available to a depth of 8 yards in the area outlined on Plate 2.

Material in borrow area B-5 consists of slope-wash derived from weathered volcanic rock. In places weathered rock is visible near the ground surface. The weathered material classifies as sandy clay. In general, this borrow area would supply a good quality, slightly plastic, impervious material of high strength. However, the volume of material available is only about 96,000 cubic yards.

TABLE 6

DESCRIPTION OF BORROW AREAS AND
PROPERTIES OF CONSTRUCTION MATERIALS

Borrow Area	Classification of Material	Probable Use	Overburden		Depth to Water (feet)	Estimated Usable Volume (1,000 cu. yd.)	Specific Gravity		Maximum Density (lbs./ft.^{3})	Optimum Moisture (percent)	Permeability[1] (Laboratory) (feet/day)	Angle of Internal Friction (degrees)	Cohesion (tons per sq. ft.)	Liquid Limit (percent)	Plasticity Index (percent)
			Type	Depth (feet)			+4 in.	-4 in.							
B-1	Silty sand, gravelly sand, bouldery and cobbley sand	Semi-pervious	Root zone	3	0 to 11	1,500	2.40	2.67	107.2	16.6	0.1 to 0.6	37.4	0	---	Non-plastic
B-2	High plastic silt, gravelly sandy silt	Impervious	Organic silt and sand	2	None	2,000	None	2.70	82.4	34.8	0.001	24.5[2] 34.0[3]	0.7 0.0	73[4]	22[4]
B-3	Sand, gravel, cobbles, and boulders	Pervious	None	0	0 to 6	1,500	2.80	2.72	130	8.4	---	---	---	---	---
B-4	Silts and clays combined with cobbles, gravels, and sand	Semi-pervious	Coarse terrace deposits	10 to 14	Not Known	1,300	---	2.85	---	---	---	---	---	---	---
B-5	Gravelly, sandy, silty clay	Impervious	Root zone	1	None	100	None	2.76	114.3	17.2	0.00007	34.0	0.6	34	12
B-6	Sandy silt, silty sand, clayey sand	Impervious	Root zone	0 to 3	None	200	None	2.75	111.1	18.4	---	---	---	36	12

1/ At 100 percent of maximum compaction

2/ Consolidated, drained samples

3/ Consolidated, undrained samples

4/ Tests on samples not air-dried

--- Not determined

The material in borrow area B-6 apparently was derived from a slightly different rock type than that in B-5. Classification tests showed the material to be a sandy silt or clayey sand. Although this material may not be as impervious as the material in borrow area B-5, it would probably be suitable for impervious fill. Approximately 200,000 cubic yards of this material are available within the area shown on Plate 2.

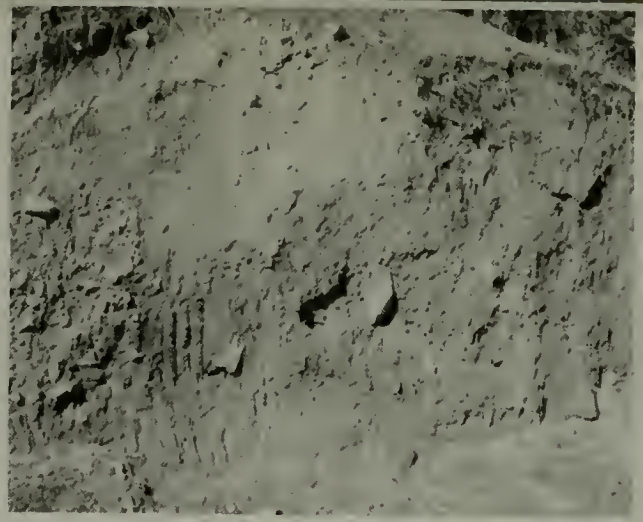
Semipervious Material. Borrow areas B-1 and B-4 were investigated in the search for semipervious material. Semipervious materials would be used in a transition zone between pervious and impervious materials in the dam embankment.

The material in B-1 consists of silty sand with generally 10 percent or more of angular volcanic rocks larger than 3 inches. The area was sampled with a backhoe and laboratory tests were conducted to determine compaction requirements and permeabilities. This material would be suitable for use in a filter or transition section since it is somewhat permeable and is nonplastic. A practically unlimited volume of material can be obtained in this area.

Borrow area B-4 is composed of layers of lake-deposited silty sands, sandy gravels, and clayey gravel. The area is overlain by a coarse terrace gravel which would have to be removed to use the underlying material for semipervious material. Because of the wide variety of materials present, it appears that selective borrowing would be required to obtain material for a particular use. The total volume of fill available in this area would be over 1 million cubic yards, but because several types of material are mixed together, further exploration and testing would be required to delineate the various materials.

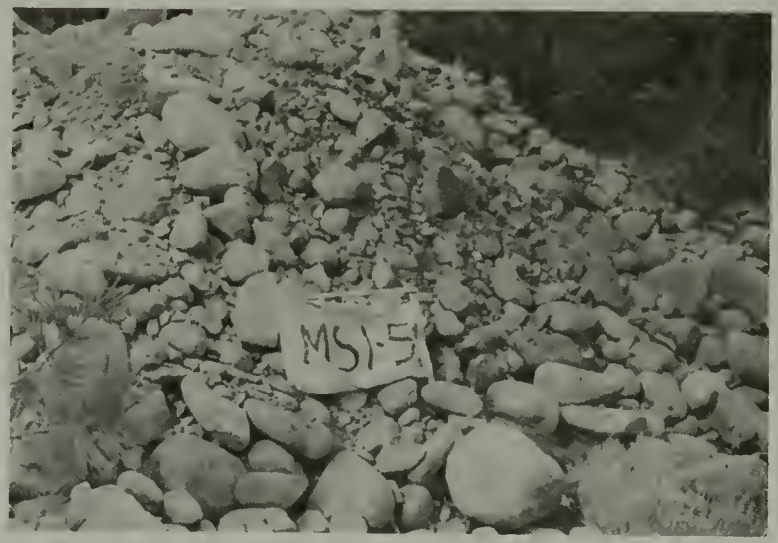
Pervious Material. Extensive deposits of coarse, well-rounded gravel are present along the active stream channel upstream from the damsite. Ten test pits ranging from 8 to 15 feet deep were dug in borrow area B-3 by the Division of Highways in 1960. None of the pits reached bedrock. It is estimated that in borrow area B-3 over 1.5 million cubic yards of material would be available. The material is very coarse and would provide suitable drainage for a pervious section in the dam embankment. Many boulders over 2 feet in


material
Borrow Area
B-2
Box Canyon Dam Crest
Semipervious
Borrow Area
B-1
Material
row Area
B-3



Borrow Area B-1

Borrow Area B-2



Borrow Area B-3

The photograph on the opposite page shows the location of the proposed borrow areas with respect to the damsite. The photographs on this page are typical of the material found in each of the borrow areas shown.

diameter are present in the gravels. Separated from the smaller cobbles, these boulders would make suitable riprap if properly placed. The results of testing conducted by the Division of Highways on the gravel material are tabulated in the Engineering Geology Office Report.

Physical Features and Costs

The Box Canyon Project has three main physical features related to major items of cost. These are (1) the dam and appurtenant structures, (2) the project lands, and (3) the recreation facilities. In this chapter the estimated costs of all project features will be presented. The designs and criteria used to prepare these cost estimates will also be discussed.

The dam and appurtenant structures were designed, in accordance with standard engineering principles, to satisfy the purposes of the project by use of the most economical combination of embankment, spillway, and outlet works. Safety of the structure was at all times considered paramount. The land included within the project boundary was considered to be the minimum amount required to properly develop and utilize the potential water-associated recreation. Recreation facilities were designed to meet standards established by the Department of Water Resources and the Department of Parks and Recreation.

Although final design of the project facilities will undoubtedly dictate changes, it is believed that the designs presented herein are reasonable for present conditions and that cost estimates based on these designs are adequate for comparison of benefits and costs and for appropriation of money for initial project construction.

Estimates of capital cost are based on unit prices that prevailed in 1964 and generally allow 15 percent for construction contingencies, 15 percent for engineering and administration, and 4 percent a year for interest during construction. An exception to these allowances was made for land acquisition where contingencies were estimated at 20 percent and engineering costs were included in the acquisition cost.

Annual costs include costs of operation, maintenance, replacement, and general expense, interest at 4 percent a year on the capital investment, and repayment throughout 50 years at 4 percent interest.

Dam and Appurtenant Structures

A zoned earth and gravel dam was chosen as the best type to satisfy foundation, economic, and safety requirements at the selected reservoir capacity. Pertinent features of the dam and reservoir are given in Table 7. Table 8 itemizes costs used to estimate total costs of the dam and appurtenant structures.

Embankment. The embankment section would be composed of an impervious central core of plastic silt and clay, flanked on each side by transition zones constructed of glacial drift material and covered by a pervious shell of natural stream sand, gravel, and cobbles. Plate 3 shows slopes and positions of the various zones within the embankment section.

In selecting the material for the impervious central core, the main requirement was that the material should be flexible enough to adjust to any differential settlement following construction and thereby minimize the possibility of transverse cracking in the core. Although the steep canyon walls would be shaped to prevent sharp discontinuities in their slope, it was felt that an impervious material which possessed the property of plasticity would be most desirable. Laboratory tests were conducted on soils from several sources near the damsite. These sources included glacial drift material along Wagon Creek, weathered material on the southern slope of Rainbow Ridge, lake deposits near Scott Camp Creek, and red clay material from the right abutment of the damsite. These materials would come from borrow areas B-1, B-5 and -6, B-4, and B-2, respectively, as shown on Plate 2. Because of the flexibility requirement and the results of laboratory tests conducted in 1961, primary consideration was given to the red clay material from borrow area B-2. Additional laboratory tests conducted on each of the different materials in 1964 substantiated the belief that the red clay material possessed the required flexibility; accordingly, it was chosen for the impervious core of the dam.

TABLE 7

FEATURES OF BOX CANYON DAM AND RESERVOIR

Dam and Reservoir	
Location	SE¼, Section 29, T40N, R4W, MDB&M
Stream	Sacramento River
Reservoir	
Drainage area in square miles	122
Elevation, in feet USGS datum	
Maximum water surface	3,201
Normal water surface	3,181
Minimum water surface	3,171
Storage capacity at normal water surface, in acre-feet	26,000
Reservoir area at normal water surface, in acres	430
Dam Structure	
Type	Zoned earth and gravel
Crest elevation, in feet, USGS datum	3,204
Streambed elevation, in feet, USGS datum	2,995
Height of dam above streambed, in feet	209
Crest length, in feet	1,250
Crest width, in feet	40
Slopes	
Upstream face, above berm at elevation 3,140	2:1
Upstream face, below berm at elevation 3,140	2.5:1
Downstream face	2:1
Total embankment, in cubic yards	625,000
Spillway	
Type	Ogee
Crest elevation, in feet, USGS datum	3,181
Crest length, in feet	125
Design flood surcharge head, in feet	20
Design flood residual freeboard, in feet	3
Design capacity, in second-feet	43,000
Energy dissipator	Flip bucket
Outlet Works	
Type	Steel pipe in concrete cut and cover section
Diameter, in inches	42
Maximum discharge at normal pool, in second-feet	330
High pressure slide gate, dimensions in feet	3x3
Regulating valve size, in inches	30

TABLE 8

ESTIMATED COST OF BOX CANYON DAM AND APPURTENANCES
(Based on 1964 prices)

Dam crest elevation: 3,204 feet, USGS datum
Spillway crest elevation: 3,181 feet, USGS datum
Height of dam crest above streambed: 209 feet
Spillway capacity with 3-foot freeboard: 43,000 cfs
Reservoir capacity at spillway crest: 26,000 acre-feet

Item	Unit	Quantity	Unit Price	Item Cost	Total Cost
Dam					
Diversion and care of stream	lump sum			$ 25,000	
Excavation; foundation stripping and core trench above elevation 3,150 (right abutment) and 3,125 (left abutment)	cu yd	26,500	$ 0.45	11,900	
Excavation, rock; abutment shaping	cu yd	45,700	6.50	297,000	
Excavation, rock; streambed	cu yd	6,000	5.00	30,000	
Impervious - borrow area B-2					
Strip and waste	cu yd	75,000	0.40	30,000	
Impervious - Zone 1	cu yd	188,000	0.55	103,500	
Transition - borrow area B-1					
Strip and waste	cu yd	15,000	0.30	4,500	
Transition - Zone 2	cu yd	74,000	1.00	74,000	
Pervious - borrow area B-3					
Strip and waste	cu yd	30,000	0.30	9,000	
Pervious - Zone 3	cu yd	423,000	0.78	330,000	
Embankment					
Impervious - Zone 1	cu yd	146,000	0.20	29,200	
Transition - Zone 2	cu yd	71,000	0.20	14,200	
Pervious - Zone 3	cu yd	395,000	0.20	79,000	
Riprap	cu yd	6,000	1.50	9,000	
Rock - dam toe	cu yd	7,000	1.10	7,700	
Special compaction	cu yd	6,000	2.00	12,000	
Drill and grout	lin ft	7,700	10.00	77,000	
Subtotal					$1,143,000
Left Abutment Protection					
Consolidated glacial drift					
Excavation	cu yd	360,000	0.30	108,000	
Embankment	cu yd	314,000	0.20	62,800	
Slope protection					
Processed stream gravel	cu yd	75,000	1.50	112,500	
Pit-run stream gravel	cu yd	50,000	0.75	37,500	
Downstream drain					
Excavation	cu yd	4,500	0.30	1,400	
Embankment	cu yd	4,500	0.20	900	
Processed stream gravel	cu yd	4,500	1.45	6,500	
Subtotal					$ 329,600

(continued on next page)

TABLE 8 (continued)

ESTIMATED COST OF BOX CANYON DAM AND APPURTENANCES

Item	Unit	Quantity	Unit Price	Item Cost	Total Cost
Spillway					
Excavation, common	cu yd	106,400	$ 0.75	$ 79,800	
Excavation, rock	cu yd	53,370	2.00	106,800	
Concrete					
Weir and bucket	cu yd	2,300	40.00	92,000	
Walls	cu yd	2,100	80.00	168,000	
Chute floor	cu yd	1,800	40.00	72,000	
Cement	bbl	6,500	5.50	35,800	
Structural backfill	cu yd	4,100	4.00	16,400	
Reinforcing steel	lb	421,000	0.15	63,200	
Anchor bars	lin ft	5,100	3.00	15,300	
Drains	lin ft	3,900	5.00	19,500	
Spillway bridge	lump sum			56,000	
Subtotal					$ 724,800
Outlet Works					
Excavation, rock	cu yd	2,500	5.00	12,500	
Concrete					
Conduit and gate chamber	cu yd	2,700	50.00	135,000	
Intake tower and valve house	cu yd	230	100.00	23,000	
Tunnel plug	cu yd	50	50.00	2,500	
Cement	bbl	4,100	5.50	22,600	
Reinforcing steel	lb	440,000	0.15	66,000	
Steel					
Steel pipe - 42"	lb	40,000	0.75	30,000	
Trashrack	lb	6,000	0.50	3,000	
Howell-Bunger type valve - 30"	lump sum			20,000	
H.P. slide gate - 36" x 36"	lump sum			24,000	
High-level outlet works	lump sum			5,000	
Subtotal					343,600
TOTAL					$2,541,000
Engineering and administration					381,000
Contingencies					438,000
Interest during construction at 4% per year					134,000
TOTAL COST OF DAM AND APPURTENANCES					$3,494,000
Reservoir Clearing and Relocations					
Clearing to elevation 3,185	acres	345	230.00	79,000	
Road relocation	miles	4.3	75,000	323,000	
Sewage plant relocation*	lump sum			57,000	
Subtotal					459,000
Engineering and administration					69,000
Contingencies					79,000
Interest during construction at 4% per year					24,000
TOTAL COST OF RESERVOIR CLEARING AND RELOCATIONS					631,000
TOTAL CAPITAL COST OF DAM AND RELOCATIONS					$4,125,000

* Includes cost of land acquisition

The main problem in using the red clay would be in achieving proper compaction when it is placed in the embankment. Tests indicate that the natural water content of the material is well above optimum. Experience with dams that have been constructed with the same type of material indicate that it is important to compact the fill near its optimum water content by drying without any rewetting during placement. If the material is dried below optimum and then rewetted, its physical make-up can be altered and the potential flexibility substantially decreased. Therefore, it will be necessary that only shallow layers be removed from the borrow area and that the material be air-dried to optimum moisture content by harrowing and working before it is placed in the fill. The additional care which must be taken is reflected in the high unit price for the material, as shown in Table 8.

The transition zones between the impervious core and the pervious gravel shell would consist of well-graded sands and gravels. Because the pervious shell material is made up of only a small amount of fines, it is necessary that a transition zone be provided to prevent migration of the core material into the pervious zones. Mechanical analysis of the glacial drift material from borrow area B-1 shows that this material falls within the range of good transition material in its natural state. No processing of the material prior to placing would be required.

Material for the pervious shell would come from the natural stream gravels and cobbles available in borrow area B-3 in the Sacramento River streambed about 4,000 feet upstream from the damsite. Quality of the material was investigated by laboratory tests for soundness, specific gravity, and absorption. Samples of material from test pits dug by the Division of Highways in 1961 were graded and found to be suitable for the pervious shell. (Division of Highways tests also indicate that this material would be suitable for concrete aggregate.)

Stability of the embankment section was checked by the "Swedish Circle Method". The properties of the materials used in the stability analyses were generally based on results of laboratory tests. All critical reservoir levels affecting the embankment were checked using a seismic loading equal to one-tenth the acceleration of gravity. Table 9 presents the properties of the materials used in the stability analyses.

TABLE 9

PROPERTIES OF MATERIALS USED IN THE EMBANKMENT STABILITY ANALYSES

	Maximum Dry Density ($lbs/ft.^3$)	Moist Density ($lbs/ft.^3$)	Saturated Density ($lbs/ft.^3$)	Angle of Internal Friction (degrees)	Cohesion ($tons/ft.^2$)
Impervious Core	82	110	115	30	0.5
Transition*	130	135	145	38	0
Pervious Shell	130	135	145	38	0

* Design values for the shell zone were also applied to the transition zone since slight differences in the properties would have little effect on the analyses.

To prevent the possibility of piping of fine materials through the lake deposits in the left abutment, a relatively impermeable blanket of selected materials would be placed on the reservoir side of the abutment. Location of the area requiring treatment is shown on Plate 3. The natural slope of this portion of the abutment is about 2:1 toward the reservoir. To prevent possible sloughing of the overlying glacial drift material under long-term saturation, and to obtain material for the compacted blanket covering the lake deposits, this slope would be stabilized by flattening to 3:1. Over this flattened and compacted area, which extends from the dam about 1,700 feet up Wagon Creek and from the Wagon Creek streambed to about elevation 3,200 feet, a 5-foot layer of stream gravels would be placed to prevent erosion of the compacted materials.

Since there is seepage into the glacial drift material from further up the ridge, the stability of this portion of the abutment was insured by providing a downstream filter to provide maximum drainage. The location of the filter is shown on Plate 3. The filter would be constructed by benching the abutment and replacing the materials removed with specially processed and graded sands and gravels.

Observation wells should be constructed in this abutment before the reservoir is filled so that a constant check may be made on the level and movement of water through the abutment.

Spillway. An uncontrolled spillway in the right abutment would consist of an unlined approach channel, a 125-foot-long concrete ogee weir with crest at elevation 3,181 feet, and a 475-foot-long converging concrete-lined chute. The approach channel will be founded on competent andesite and will not require a concrete lining. The weir will also be founded on andesite at the axis of the dam. The chute, founded on volcanic tuff, would terminate in a flip bucket, founded on andesite, which would break the force of the water entering the stream channel.

The spillway is designed for a maximum discharge of 43,000 second-feet with a surcharge of 20 feet. Three feet of freeboard on the dam was allowed for wave action at maximum spillway capacity. This maximum discharge capacity was determined from a flood routing study based on reservoir inflow from the probable maximum flood.*

Outlet Works. Two outlet facilities would be incorporated in Box Canyon Dam to provide means for temperature control of water released downstream. A high-level outlet would be installed to draw water from near the reservoir surface when the spillway would not be in operation. This outlet would have a capacity of 40 second-feet with the reservoir at its minimum operation level at elevation 3,171 feet. A low-level outlet would draw water from near the bottom of the reservoir. The low-level outlet would have a capacity of 330 second-feet with the reservoir at normal pool elevation.

Requirements for a high-level outlet would be met with a conduit through the spillway weir. The conduit would be 3 feet square, formed in the weir concrete. Releases would be controlled with a hand-operated

* This is the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the drainage basin.

30- by 30-inch low-head slide gate. The bottom of the slide gate would be at elevation 3,166 feet.

The low-level outlet facilities would be housed in a horseshoe-shaped concrete conduit, sized for diversion of the river during construction. While the river is diverted through the conduit, a 60-foot-high intake tower would be constructed to assure that the outlet trashracks would be above the reservoir sedimentation level. To permit reservoir storage upon completion of the dam, a concrete plug would be constructed in the diversion conduit near the dam axis. A 42-inch steel penstock would be installed from the plug to a valvehouse at the downstream toe of the dam. A 36- by 36-inch high-pressure slide gate would be installed in the penstock near the plug for emergency closure of the outlet works, and a 30-inch regulating valve would be installed at the downstream end of the penstock to dissipate energy and provide regulated stream releases. In case of emergency closure of the low-level outlet works, water could be released from the high-level outlet for the downstream fishery.

Stream Diversion During Construction. The Sacramento River must be diverted to one side of the stream channel during construction of the diversion works required for construction of the dam. Because the width between the canyon walls is narrow, about 60 feet average, construction of the diversion works would be delayed until summer when streamflow is low. Construction could begin in July when the average streamflow is about 70 second-feet and the maximum likely to occur would be about 200 second-feet.

The diversion works was sized to permit diversion of the stream as early as possible during the second construction season. A 7-foot horseshoe-shaped conduit would pass a flow of about 1,100 second-feet with a 45-foot cofferdam at the upstream end. The cofferdam would later be incorporated in the main dam embankment. Peak flow recorded in May is 1,300 second-feet, so it was assumed that placement of embankment could begin by June 1 and be completed by October 15, before the fall rains begin.

Project Land Acquisition

Acquisition of the land required to fulfill the project purposes involves two major items: (1) acquisition of the land in fee title or by use permit, and (2) relocation of existing facilities that would still be required

following project construction. Land acquisition costs were based on estimated current value of the land and improvements plus appropriate costs incurred during acquisition, with an allowance for unforeseen contingencies. The current value of the land and improvements was estimated from recent sales of similar land in the general area. Costs of relocating facilities now existing within the project area were estimated on the basis of providing a facility with the same utility in a nearby area.

Land Acquisition. The area required to provide lands for the dam and reservoir and for development of recreation facilities required to meet the estimated water-associated recreation demands is shown on Plate 4. This area totals 2,240 acres. Only 80 acres is federal land within the Shasta National Forest Boundary. About 200 acres are owned by the City of Mt. Shasta and used for their sewage and waste disposal area. The remaining land is in private holdings. A use permit could be acquired from the Forest Service for 40 acres of their land in section 25 since this land will only be used for the road relocation. However, the 40 acres located in section 30 should be acquired for project use by a trade for land of equal value since recreation facilities will ultimately be located there. A tentative agreement has been reached with the City of Mt. Shasta whereby title to their land would be transferred to the project owner in return for relocation of their sewage and waste disposal facilities. Relocation of these facilities is described in the following section. It is assumed that all private lands would be acquired in fee title.

The 2,240 acres of project lands includes two farms which contain approximately 300 acres of developed agricultural land, about 40 acres of stream gravels, some of which are being used in a gravel crushing and processing operation, and about 200 acres in the northeast corner of the area that are presently being subdivided. The remaining 1,700 acres are cut-over timber land.

Of the lands proposed for acquisition, 550 acres would be within the maximum high water line of the reservoir. About 1,390 acres adjacent to the reservoir would be suitable for recreation development to fulfill the estimated water-associated recreation needs. Most of this acreage would be well suited for development of campsites and picnic areas. That area not used for camp and picnic sites would be developed for beach areas, boat launching ramps, parking areas, concession areas, overlook areas, and access roads,

or would be left in its natural state to preserve the scenic environment of the area. Proposed areas devoted to these types of development are shown on Plate 4.

To insure that deer populations would not be reduced by construction of the Box Canyon Project, about 300 acres in the southeast corner of the project area were designated for deer range improvement. This area will be managed to provide additional deer forage over that now available in the same area.

Each parcel of land was considered separately and the value was determined by a market analysis method which compared recent sales of similar property in the immediate area. The Siskiyou County Recorder and local real estate agencies supplied data on sales of property in or near the project area. The total acquisition cost of the 2,000 acres (not including 200 acres which belong to Mt. Shasta City or 40 acres of Forest Service land) is estimated to be $1,230,000, including severance damages, acquisition overhead costs, and contingencies.

During the study reported on in Bulletin No. 100, a land acquisition cost estimate was made for essentially these same parcels of land in August 1961. At that time the estimated cost was $450,000. Since 1961, land speculation and the beginning of land subdivision in and around the project area have skyrocketed land values. A land economics study conducted during the current study indicates that the upward trend of land values will continue, although the rate of increase will not be so great. If the land values are allowed to continue to climb, the cost of project land acquisition may soon make the project costs greater than the primary benefits. Siskiyou County should attempt to prevent further land speculation by purchasing the required land as soon as possible, by land zoning restrictions, or by some other method.

Relocation of Existing Facilities. Facilities now located in the proposed dam and reservoir area which must be relocated are the Mt. Shasta sewage and waste disposal area and the county and Forest Service roads. There are no public utilities or other private facilities which would require relocation.

The present methods of sewage and waste disposal employed by Mt. Shasta City are sewage oxidation ponds and a waste disposal dump located in the NW¼, SW¼, Section 28, T4ON, R4W, MDB&M. Since this area is located on the left abutment of the damsite, both facilities must be relocated to a more desirable area. A suitable area has been located about one-half mile southeast of the present site and is shown on Plate 4. This site was selected for several reasons:

1. It is near enough to the present site so that only a minimum amount of additional sewer outfall line is required.
2. Topography and soil conditions at the relocation site are as good as or better than those at the present site.
3. Most of the area of the proposed new site is in the restricted building zone required for approach clearance to the airplane runway being constructed on the east side of the proposed reservoir. This type of development would be quite compatible with regulations of the California Aeronautics Division and the Federal Aviation Agency.
4. Sufficient land is available at this site for both sewage and waste disposal operations.
5. Access to the area from the existing road would be excellent.

Considerations of present and future needs of the city were discussed with the Mt. Shasta City Director of Public Works. It was agreed that a total of 60 acres in the area shown on Plate 4 would meet the city's requirements. About 50 acres would be adequate for development of sewage oxidation ponds and the balance for a dump area. The southwest corner of the area contains a huge gulch which could be used for the waste disposal area.

The estimated cost of relocating the sewage and dump facilities, including engineering and contingencies, is $75,000. This cost includes land acquisition, extension of the sewer outfall line from its present location to the new site, construction of an improved road from the county road to the dump site, and fencing the boundary of the area.

In return for these relocated facilities, the City of Mt. Shasta would give title to their present land holdings within the project area at no cost the project.

An all-weather, asphalt-surfaced road would be constructed from the existing county road, which intersects Valley Road near the Southern Pacific Railroad Crossing, across the crest of the dam and around the south side of the reservoir. There it would join the existing Forest Service road which parallels the Sacramento River above the reservoir site. This proposed road is 4.3 miles long and is shown on Plate 4. The road would provide access to the county road leading to Castle Lake and to the South Fork service road (40N30) which parallels the Sacramento River to the Gumboot Lake area. A low-water crossing would be provided across the Sacramento River above the reservoir. This crossing would provide access to the Deer Creek Forest service road (40N27) during periods of low water when the fire hazard is greatest. The crossing is designed to pass low summer and fall streamflow but would be overtopped by high winter and spring flows. The crossing could also be used by recreationists to reach campgrounds on the north side of the reservoir.

The proposed road relocation and river crossing have been reviewed by the Forest Service and the Siskiyou County Road Commissioner and were approved as an acceptable replacement for existing roads.

The total estimated cost of the road relocation, including engineering, contingencies, and interest during construction, is $440,000. This would provide for all grading, drainage facilities, and base material required for a 32-foot roadbed with a 24-foot width of asphalt surfacing. No additional right-of-way costs would be incurred since the road would be relocated entirely on project lands. All Siskiyou County standards for road construction would be met so that the completed road could be turned over to the county for maintenance.

Recreation Facilities

In estimating recreation use at the Box Canyon Project, it was assumed that adequate recreation facilities would be available to satisfy the needs of the recreationists. Therefore, the number and type of recreation units installed at any particular time during the period of economic analysis were based upon the estimated number of recreationists expected to use the project at that particular time. Table 19 in Chapter 5 presents the estimated number of recreationists expected to use the project during the 50-year period of economic analysis.

Camping Facilities. Criteria used to determine the number of camp facilities required to supply the predicted demand at any time during the economic life of the project were as follows:

1. One camping party uses one campsite for one day and one night.
2. The average camping party is composed of 4.2 people.
3. Thirty-five percent of the total annual use of camping facilities occurs during the peak month of use.
4. Camping facilities should meet the average daily demand during the peak month of use.
5. An overload of 10 percent during the peak month of use would be allowable before additional facilities would be installed.

Computations using these criteria resulted in the curves presented in Figure 2. Curve 1 shows the number of camping facilities required for predicted demand during the entire study period. Curves 2 and 3 were used to develop limits in staging the installation of camping facilities and to show limits for installing new project facilities whenever the demand exceeds the capacity by 10 percent.

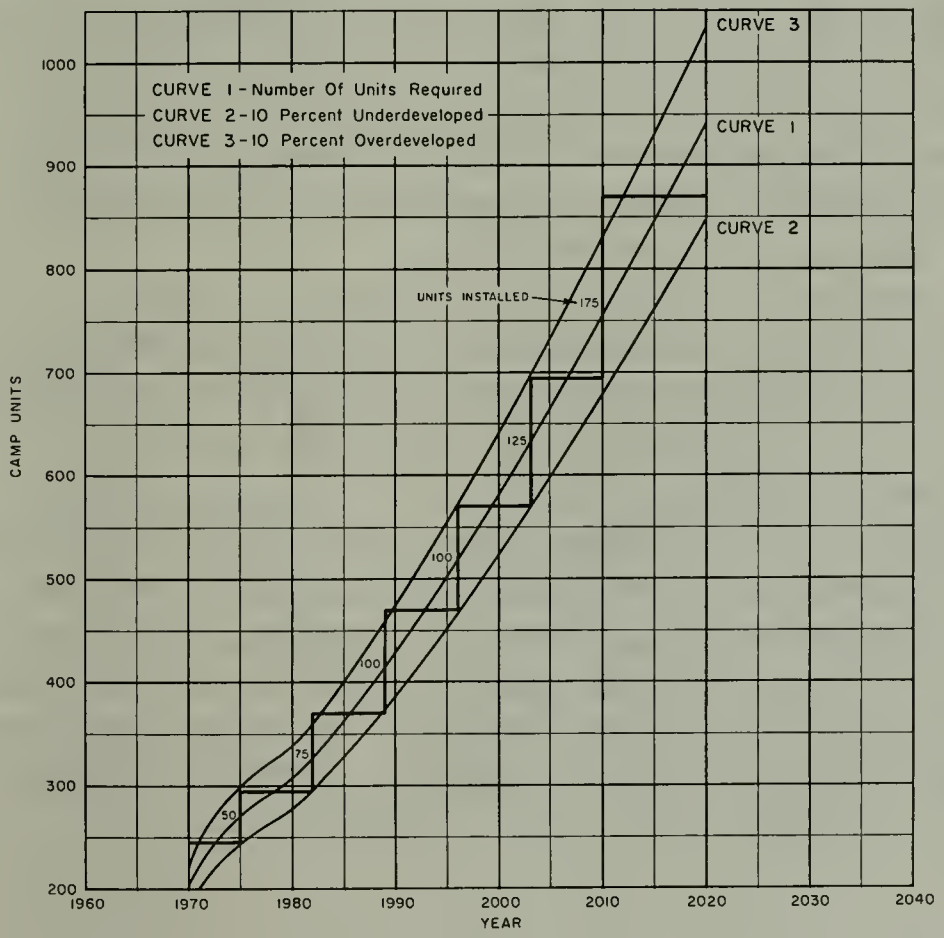


Fig. 2. STAGING OF CAMP UNIT INSTALLATION AT BOX CANYON RESERVOIR

Day-Use Facilities. Comparison of the tentative Box Canyon Reservoir with similar reservoirs, and interpretation of the 1958 recreation use survey at Dwinnell Reservoir, resulted in the following estimated percentages of day-users who would participate in various activities at Box Canyon:

1. Fishing, 40 percent
2. Boating and water skiing, 20 percent
3. Swimming, 20 percent
4. Picnicking, 20 percent

Fishing was assumed to be the most attractive day-use activity because of the high potential of Box Canyon as a trout fishery. High-speed boating and water skiing may not be as popular here as elsewhere because of the limited size of the proposed reservoir compared with the large surface areas of other reservoirs in this section of the State. Adequate zoning of the reservoir should be provided to prevent conflicts in use.

Picnic units to be provided generally would consist of a fireplace, table, and parking area. Water and sanitary facilities would be shared by several units. All units would meet state park standards. Criteria used to determine the number of picnic units required to supply the predicted demand at any time during the economic life of the project were as follows:

1. One and three-fourths day-use parties use one picnic unit daily during the peak month of use.
2. The average day-use party is composed of 4.2 people.
3. Picnic units should provide for all picnickers, one-quarter of the boaters, and incidental use by fishermen and swimmers.
4. Picnic units should meet the average daily demand during the peak month of use.
5. An overload of 10 percent during the peak month of use would be allowable before additional facilities would be installed.

Computations using these criteria resulted in the curves presented in Figure 3. Curve 1 shows the number of picnic facilities required for predicted demand during the entire study period. Curves 2 and 3 were used to develop limits in staging the installation of picnic facilities.

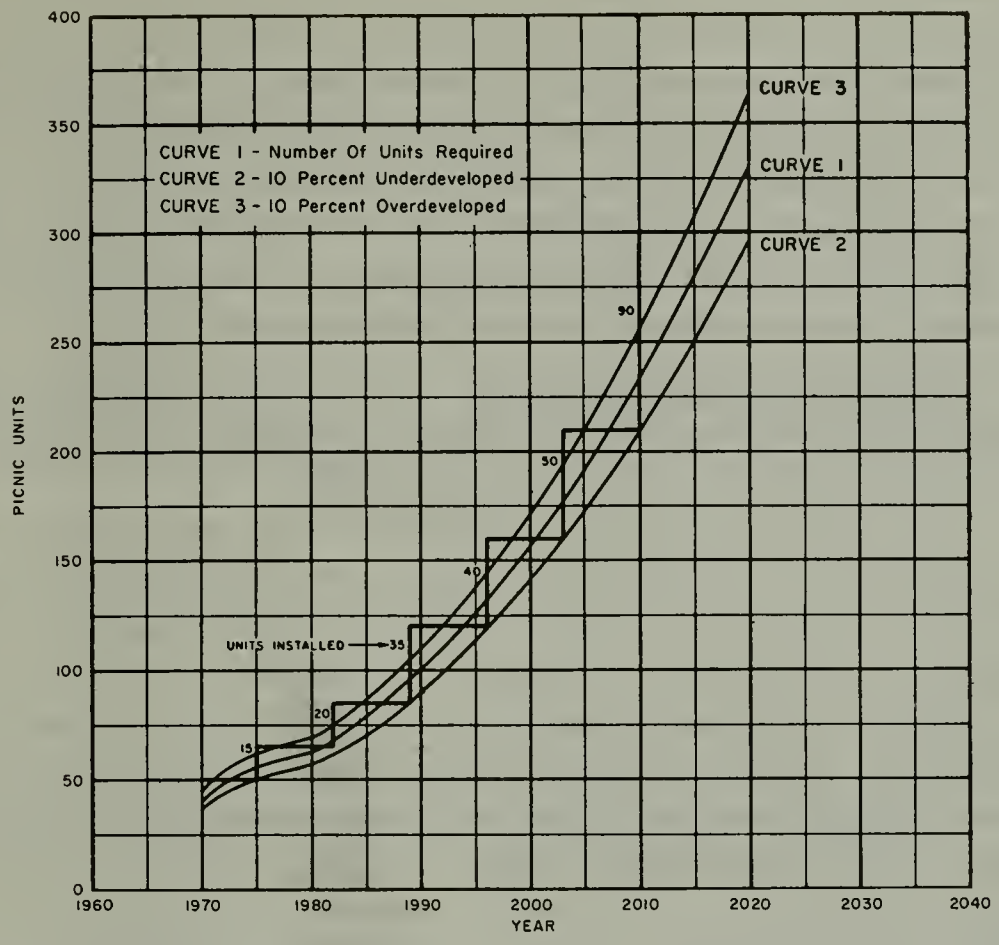


Fig. 3. STAGING OF PICNIC UNIT INSTALLATION AT BOX CANYON RESERVOIR

Boat launching ramps, beach areas, sanitary facilities, bathhouses, and parking areas, in addition to picnic facilities, would be provided for day-users.

Sightseer Facilities. An overlook area near the dam would be provided specifically for sightseers. This area would include a parking area, water and sanitary facilities, and a vantage point from which the dam and reservoir could be viewed. Undoubtedly, many sightseers would also drive through the recreation area to obtain a closer view of the area surrounding the reservoir.

Commercial Facilities. It is now the policy of the State Department of Parks and Recreation to encourage privately financed commercial developments within the project boundaries. These developments are, of course, under the

jurisdiction of the State when they are constructed in a State Park or Recreation area. However, the development of privately financed commercial facilities would be possible whether the Department of Parks and Recreation or a local agency operates the project. Since visitors to commercial facilities would utilize Box Canyon Reservoir in the same manner as would other recreationists, no distinction was made between them and other recreation visitors.

Costs of Recreation Facilities. Estimates of construction, operation, maintenance, and replacement costs of onshore recreation facilities were provided by the Department of Parks and Recreation.

Installation of future recreation facilities were staged to provide adequate facilities for expected use. Table 10 shows the staging of camp and picnic units which make up the majority of future development. A detailed breakdown of the recreation facilities to be installed at each stage of development throughout the period of economic analysis was used to estimate construction costs. Layout of the required facilities was accomplished by on-site inspection, and unit costs were based on average, recent construction costs for similar facilities in similar areas.

TABLE 10

STAGED INSTALLATION OF CAMP AND PICNIC FACILITIES

Year	Recreation Units				Total
	Camp (from Figure 2)		Picnic (from Figure 3)		
	Installed	Total	Installed	Total	
1970	245	245	50	50	295
1975	50	295	15	65	360
1982	75	370	20	85	455
1989	100	470	35	120	590
1996	100	570	40	160	730
2003	125	695	50	210	905
2010	175	870	90	300	1,170
2020	-	870	-	300	1,170

Annual costs of operation of the recreation area and maintenance and replacement of the recreation facilities were also estimated by the Department of Parks and Recreation. These estimates were based on average costs incurred at similar projects. Operation and maintenance costs were estimated on the basis of 30 cents per recreation visitor-day. Annual replacement costs were estimated as 3.5 percent of the capital cost of installed facilities.

Table 11 presents a summary of the estimated construction, operation, maintenance, and replacement costs for the onshore recreation facilities during the period of economic analysis. The costs of the water supply and waste disposal facilities are included in the costs presented. The value of future expenditures reduced to a common time basis (present worth) is also presented in this table.

TABLE 11

BOX CANYON PROJECT RECREATION COSTS

Year	Time Interval in Years	Estimated Recreation Costs					Total Present Worth
		Installation of Recreation Facilities 1/		Operation, Maintenance, and Replacement			
		Total	Present Worth	Annual 2/	Total for Time Interval	Present Worth	
1970		$ 1,141,000	$ 1,141,000	$ 82,000	$	$	$ 1,141,000
	5				460,000	416,000	416,000
1975		284,000	234,000	100,000			234,000
	7				790,000	566,000	566,000
1982		254,000	159,000	126,000			159,000
	7				980,000	533,000	533,000
1989		309,000	147,000	154,000			147,000
	7				1,200,000	497,000	497,000
1996		330,000	119,000	189,000			119,000
	7				1,460,000	458,000	458,000
2003		343,000	94,000	228,000			94,000
	7				1,780,000	425,000	425,000
2010		532,000	111,000	280,000			111,000
	10				3,070,000	525,000	525,000
2020		--	--	335,000			
Total			$ 2,005,000			$ 3,420,000	$ 5,425,000

1/ Includes cost of water supply and sanitary facilities.
2/ Estimated to be 30 cents per visitor-day for operation and maintenance; 3.5 percent of total cost of installed facilities for replacement.

Water Supply System and Sanitary Facilities

Even at early stages of project development, water supply and sanitary waste disposal facilities comparable to those of a small town will be required. Several alternative methods for developing the water supply and disposing of wastes were considered. Criteria used in selecting the proposed methods included water quality, construction and operating costs, legal considerations, local health regulations, and safety.

Water Supply. The following sources of water supply were considered:

1. Diversion from Big Springs Creek near the Mt. Shasta fish hatchery.
2. Purchase of water from Mt. Shasta City.
3. Pump water from Box Canyon Reservoir.
4. Diversion from Deer Creek, Sacramento River above the reservoir, or from Scott Camp Creek.

Diversion from Scott Camp Creek was found to provide the most economical source of water. The only development at present in the watershed tributary to Scott Camp Creek is a church camp used only in the summer. Future use under the Forest Service multiple-use plan includes a ski area, but this would probably be far into the future. Samples of the water were collected, tested, and found to be of suitable quality for domestic use with only minimum treatment. Quality of this water is discussed in more detail in Chapter 2.

Measurements of summer flow in Scott Camp Creek at various times since 1960 indicate that the streamflow would probably never be less than 1 second-foot (646,000 gallons per day) at the diversion point. In the past, water has been diverted for agricultural purposes just below the proposed diversion site. The stream is fed by springs, and long-time residents do not remember the stream ever being dry.

With adequate storage a diversion of about 0.2 second-foot (130,000 gallons per day) at the beginning of project operation and 0.6 second-foot (400,000 gallons per day) at maximum development would be adequate to supply the requirements of the recreation area. This would include the administration area but would not include the group camp areas on the north side of the reservoir or the concession area. These areas would be served by pumping from ground water or from the reservoir.

The water supply system would consist of a diversion structure in Scott Camp Creek at about elevation 3,550 feet USGS datum, a pipe sized for maximum future requirements leading from the diversion to treatment and storage facilities, and distribution lines leading from the storage tanks to the recreation and administration areas. Plate 4 shows a layout of the water supply system and depicts the staged installation of future facilities to meet future demands.

Since the entire system would operate by gravity flow, operation and maintenance costs would be very low. A summary of the estimated initial construction costs is included in Table 12.

Sanitary Facilities. Several methods of sewage disposal were investigated. These were:

1. A collection system leading to the relocated Mt. Shasta City sewage oxidation ponds.
2. A collection system leading to a self-contained treatment plant within the recreation area.
3. Installation of individual septic tanks at each of the comfort stations.

Preliminary cost estimates indicated that the use of septic-tanks would be most economical.

Soil permeability tests conducted at the site in accordance with the U. S. Public Health Service "Manual of Septic-Tank Practice" indicate a uniform percolation rate of about 1 inch of water in 3.3 minutes. This is considered very good for waste water disposal. All septic-tanks and leaching fields would be at least 200 feet from the reservoir to avoid the possibility of discharge into the reservoir. This plan for sewage disposal has been reviewed by Siskiyou County health officials and would comply with the local health regulations.

Comfort stations would be provided at convenient locations in all areas of use. Showers and restrooms with flush toilets would be provided for camping and beach areas. In camping areas, a combination building which provides toilets and showers with hot running water would be provided for about every 25 camp units. Table 12 shows the number and types of facilities

TABLE 12

ESTIMATED COST OF INITIAL
WATER SUPPLY AND SANITARY FACILITIES

Feature	Unit	Unit Cost	Capital Cost
WATER SUPPLY			
Access road to diversion site	lump sum	$	$ 5,000
Diversion dam, concrete	cu yd	100.00	1,000
6-inch pipe, 3,200 feet	lin ft	4.50	14,400
Redwood storage tank, 90,000 gallons	gal	0.15	13,500
Hypochlorinator-filter, 45,000 gpd	lump sum		1,350
4-inch pipe, 6,700 feet	lin ft	3.25	21,800
3-inch pipe, 2,600 feet	lin ft	3.00	7,800
2-inch pipe, 1,100 feet	lin ft	2.10	2,300
1-inch pipe, 12,300 feet	lin ft	1.10	13,500
Hose bibs with standpipes, 57	each	40.00	2,180
Wharf hydrants, 6	each	140.00	840
Fire hydrants, 2	each	400.00	800
Dam overlook area - Develop drill hole LA-4 including pumphouse, pump, pressure tank, chlorinator, and distribution system (up to 57,500 gpd)	lump sum		3,000
Subtotal			$ 87,500
SANITARY FACILITIES			
Combination buildings, 5	each	17,500	$ 87,500
6-fixture comfort stations, 5	each	12,500	62,500
Combination 6-fixture restroom, dressing room (beach area), 1	each	15,000	15,000
4-fixture comfort station (overlook and boat ramp), 2	each	10,000	20,000
Subtotal			$ 185,000
Total			$ 272,500
Engineering and Administration			40,900
Subtotal			$ 313,400
Contingencies			47,000
Grand Total			$ 360,400

proposed and presents an estimate of the initial construction cost. The cost of septic tanks and leach fields is included in the unit cost of the sanitary facilities. Plate 4 shows the approximate locations of facilities planned for initial and future development.

A summary of the estimated initial and future water supply and sanitary facilities construction costs is included in Table 13.

TABLE 13

SUMMARY OF ESTIMATED COST OF WATER SUPPLY AND SANITARY FACILITIES

Estimated Construction Year	Capital Cost				Present Worth
	Water Supply	Sanitary Facilities	Engineering, Administration, and Contingencies	Total	
1970	$ 87,500	$185,000	$ 87,900	$360,400	$360,400
1975	9,800	27,500	12,000	49,300	40,500
1982	19,600	67,500	28,100	115,200	72,000
1989	35,900	70,000	34,200	140,100	66,500
1996	24,600	52,500	24,900	102,000	36,800
2003	44,600	70,000	37,000	151,600	41,600
2010	47,800	112,500	51,700	212,000	44,100
Total	$269,800	$585,000	$275,800	$1,130,600	$661,900

Preservation of Wildlife

A study conducted by the Department of Fish and Game indicates that deer range lost by reservoir inundation and by intensive recreation use in the project area would be detrimental to the migratory deer herd. A report on this study, "The Effects of Box Canyon Dam and Reservoir on the Fish and Wildlife Resources of the Upper Sacramento River Basin", is available for reference in the Resources Agency Library in Sacramento.

As a result of its study the Department of Fish and Game recommends that approximately 300 acres of project lands located in Sections 28, 29, 32, and 33 be set aside for deer range management to mitigate for deer range lost because of project construction. This area is delineated on Plate 4. The recommended area has been included within the project boundary and the cost of acquiring the land has been included in the project land acquisition cost.

Estimated initial cost of developing the new area is $15,000. This includes improvement of existing brush fields, seeding and fencing borrow areas, and thinning dense stands of timber. A buffer of natural vegetation will be left along access roads to preserve the natural beauty of the recreation area.

Costs of operating and maintaining the deer range were also estimated. Average annual maintenance of the range was estimated at $1,200 and annual supervision costs at $900 for a total of $2,100.

Summary of Project Costs

Estimated costs of the Box Canyon Project are presented in Table 14. These costs have been shown as initial and future expenditures. Initial expenditures represent the costs of construction required to build the project and put it into the first year of operation. Future costs, expressed in terms of present worth, are additional costs incurred during the 50-year economic life of the project, and include annual expense for operation, maintenance, and replacement, and costs of installation of future recreation facilities. The sum of initial and future expenditures represents total project costs that may be compared to total project benefits.

Initial project costs were estimated to be $6,511,000. Total project costs reduced to 1970 present worth would be $11,076,000. The average annual equivalent cost over the 50-year period with interest at 4 percent is $515,600.

TABLE 14

SUMMARY OF BOX CANYON PROJECT COSTS

Item	Capital Cost		Present Worth of Capital Cost	Average Annual Equivalent of Present Worth
	Construction Cost	Engineering, Administration, Contingencies, and Interest During Construction		
Initial Expenditures				
Dam and Appurtenances	$2,541,000	$ 953,000	$3,494,000	$162,600
Relocations and reservoir clearing	459,000	172,000	631,000	29,400
Land acquisition	1,025,000	205,000	1,230,000	57,300
Recreation facilities	781,000	1/	781,000	36,400
Water supply and sanitary facilities	272,000	88,000	360,000	16,700
Deer range improvement	15,000	1/	15,000	700
Subtotal	$5,093,000	$1,418,000	$6,511,000	$303,100
Future Expenditures				
Recreation facilities 2/	2,052,000	1/	864,000	40,200
Operation, maintenance, replacement, and general expense of dam and appurtenances	---	---	236,000 3/	11,000
Operation, maintenance, and replacement of recreation facilities 2/	---	---	3,420,000 3/	159,200
Operation and maintenance of deer range	---	---	45,000 3/	2,100
Subtotal			$4,565,000	$212,500
TOTAL			$11,076,000	$515,600

1/ Included in construction cost
2/ Includes cost of water supply and sanitary facilities
3/ Total present worth of annual expenditures

CHAPTER 5. PROJECT ACCOMPLISHMENTS AND BENEFITS

Development of a recreation-oriented water project at Box Canyon would be another step toward filling the needs of both the residents of the area surrounding the project and the people of the State of California. Californians need more water-associated recreation areas and the residents of Siskiyou County need the economic boost that would be provided by such a development.

Following are some of the reasons why residents of Southern Siskiyou County believe that the Box Canyon Project would benefit their area:

1. A need exists in their area for a water-associated recreation area which would attract and hold summer visitors. A winter sports area was developed in 1958, but to fully develop the year-round recreation potential of this area an organized summer recreation area is required.
2. Many natural streams now provide trout fishing in this area, but a properly managed reservoir trout fishery would attract many more anglers and thereby round out the area's fishing potential.
3. A reservoir at Box Canyon would provide some flood control along the Sacramento River in the Dunsmuir area.
4. The money brought into the area by the thousands of visitors to the project would give this portion of Northern California the "shot in the economic arm" it so vitally needs.

The State and Federal governments encourage and support the type of development which would be accomplished at the Box Canyon Project. They support the development of:

1. Water-associated recreation areas for the enjoyment of all the people.
2. Projects which enhance the fisheries resources.
3. Flood control works.
4. Projects in economically depressed areas.

In the following sections the proposed reservoir operation and the fisheries enhancement, recreation, and flood control accomplishments and benefits derived from the project will be described in detail.

Reservoir Operation

Evaluation of the recreation and reservoir fisheries enhancement benefits depends to a large extent upon the character of the reservoir pool that is provided. Both purposes would provide greater benefits if the water surface elevation is relatively stable rather than fluctuating widely during the year. Therefore, the reservoir should be operated on a schedule which would provide the maximum mutual benefit to the recreation and fisheries enhancement purposes while maintaining, insofar as possible, a small flood control reservation. To accomplish these purposes the reservoir should be kept as full as possible during the entire recreation season, while still providing adequate downstream releases to preserve and enhance the natural trout fishery and maintaining some winter flood storage.

Operation Criteria

The following reservoir operation criteria were established and used in the operation studies:

1. The reservoir pool shall be maintained at the highest possible level, consistent with other operating criteria, during the main recreation season of June 1 through October 1.
2. The following Department of Fish and Game recommendations for downstream releases shall be met:
   (a) At any time the reservoir is filling, provide the following releases or the reservoir inflow, whichever is less:

January 1 to February 28	150 second-feet
March 1 to May 31	100 second-feet
June 1 to July 31	75 second-feet
August 1 to September 30	50 second-feet
October 1 to October 31	75 second-feet
November 1 to December 31	100 second-feet

(b) After the reservoir fills, release the total inflow to the reservoir, minus evaporation, except release should never be below 40 second-feet.

3. Reservoir releases shall be made to provide a flood control reservation of 2,000 acre-feet at all times possible between October 10 and March 15. Reservoir drawdown for flood storage will not begin before October 1 and filling for the summer recreation pool will not commence before March 15.

Reservoir Evaporation

Average annual net evaporation from the reservoir was estimated to be 3 feet per year. This total evaporation was distributed among the months in accordance with evaporation measured at the U. S. Weather Bureau station at Lakeshore on the Sacramento River arm of Shasta Lake. The resultant estimated average net monthly evaporation (Table 15) was used in the reservoir operation studies.

TABLE 15

ESTIMATED AVERAGE NET MONTHLY EVAPORATION IN BOX CANYON RESERVOIR

Month	Net Evaporation (inches)
October	2.2
November through February	0.0
March	3.5
April	4.3
May	5.5
June	7.2
July	6.4
August	4.6
September	2.3
Total	36.0

Results of Operation Study

The reservoir was operated through the 50-year period of 1914-15 through 1963-64. This period was chosen to take advantage of the total recorded streamflow at the Sacramento River stream gaging station near the damsite and because it extends over several extremely wet and dry periods. The period is assumed to statistically represent any future 50-year period following project construction.

Table 16 is a summary of the monthly operation study. Reservoir storage at the beginning of the water year (October 1) is shown for each year of the period. This is generally the lowest reservoir level during the year, prior to the flood reservation period, since rainfall in this area usually begins in October.

TABLE 16

SUMMARY OF MONTHLY OPERATION STUDY OF BOX CANYON RESERVOIR
(in 1,000 acre-feet)

Runoff Year	Storage on Oct. 1	Inflow 1/	Water Releases and Losses			Runoff Year	Storage on Oct. 1	Inflow 1/	Water Releases and Losses		
			Evaporation	Release and Spill	Total				Evaporation	Release and Spill	Total
1914-15	0 2/	287.7	1.3	260.4	261.7	1939-40	24.4	243.9	1.4	241.1	242.5
15-16	26.0	219.7	1.4	218.3	219.7	40-41	25.8	360.2	1.4	358.6	360.0
16-17	26.0	122.7	1.4	123.0	124.4	41-42	26.0	265.9	1.4	264.5	265.9
17-18	24.3	94.0	1.4	92.0	93.4	42-43	26.0	142.9	1.4	143.0	144.4
18-19	24.9	156.8	1.4	154.5	155.9	43-44	24.5	77.5	1.4	77.7	79.1
1919-20	25.8	64.7	1.4	66.3	67.7	1944-45	22.9	131.7	1.4	129.0	130.4
20-21	22.8	255.7	1.4	251.1	252.5	45-46	24.2	172.2	1.4	170.5	171.9
21-22	26.0	110.8	1.4	111.9	113.3	46-47	24.5	100.9	1.4	99.4	100.8
22-23	23.5	108.3	1.4	105.8	107.2	47-48	24.6	159.1	1.4	156.7	158.1
23-24	24.6	49.2	1.4	50.5	51.9	48-49	25.6	136.1	1.4	136.2	137.6
1924-25	21.9	186.9	1.4	181.7	183.1	1949-50	24.1	108.6	1.4	107.9	109.3
25-26	25.7	108.1	1.4	108.7	110.1	50-51	23.4	187.2	1.4	184.6	186.0
26-27	23.7	246.5	1.4	243.0	244.4	51-52	24.6	219.0	1.4	216.2	217.6
27-28	25.8	154.5	1.4	154.2	155.6	52-53	26.0	189.2	1.4	187.8	189.2
28-29	24.7	86.9	1.4	86.6	88.0	53-54	26.0	196.2	1.4	194.8	196.2
1929-30	23.6	126.2	1.4	124.0	125.4	1954-55	26.0	107.6	1.4	108.4	109.8
30-31	24.4	59.8	1.4	60.9	62.3	55-56	23.8	243.6	1.4	240.0	241.4
31-32	21.9	93.4	1.4	92.0	93.4	56-57	26.0	155.1	1.4	153.7	155.1
32-33	21.9	104.1	1.4	101.3	102.7	57-58	26.0	345.2	1.4	343.8	345.2
33-34	23.3	99.5	1.4	98.0	99.4	58-59	26.0	141.1	1.4	140.5	141.9
1934-35	23.4	142.9	1.4	142.8	144.2	1959-60	25.2	120.2	1.4	118.3	119.7
35-36	22.1	135.4	1.4	132.6	134.0	60-61	25.7	176.3	1.4	174.6	176.0
36-37	23.5	132.9	1.4	131.6	133.0	61-62	26.0	152.4	1.4	151.0	152.4
37-38	23.4	330.7	1.4	326.7	328.1	62-63	26.0	211.1	1.4	209.7	211.1
38-39	26.0	89.0	1.4	89.2	90.6	63-64	26.0	106.5	1.4	105.7	107.1

1/ Estimated future impaired.
2/ Assumed to be a new reservoir just beginning operation.

The monthly operation study shows that the maximum expected reservoir drawdown would be only 10 feet under this operation. This would have occurred only twice during the 50-year period, in the extremely dry years of 1924 and 1932. The average annual drawdown would be less than 3.5 feet and would generally not reach that point until the first of October. Figure 4 shows that only during 16 percent of the recreation season (May through September) would the reservoir surface be more than 2 feet below normal pool elevation, and that only during about 4 percent of the time would the reservoir surface be more than 6 feet below normal pool elevation. This operation schedule will provide a recreation water surface almost equal to a natural lake.

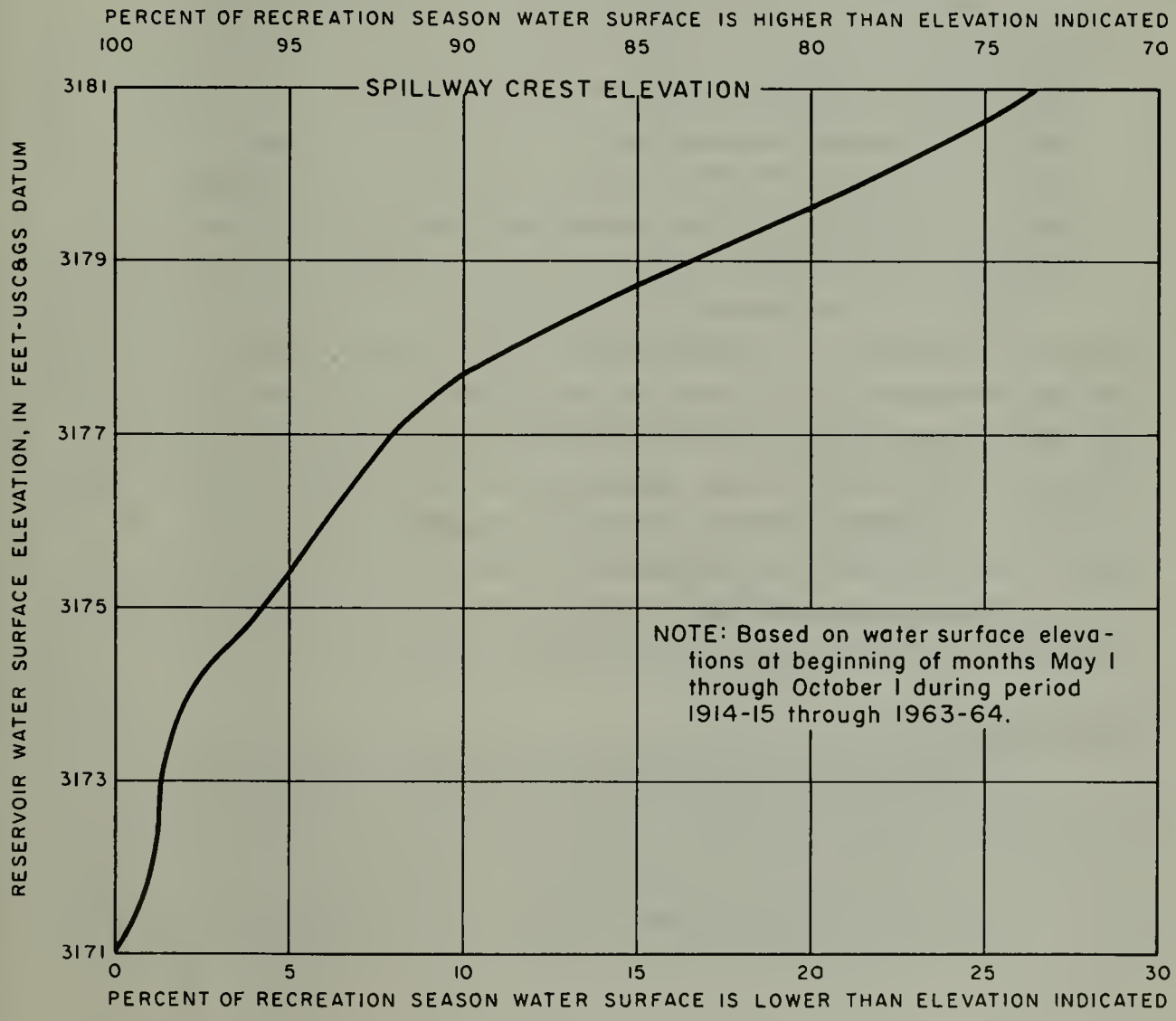


Figure 4. FLUCTUATION OF BOX CANYON RESERVOIR WATER SURFACE

Fisheries Enhancement

During this investigation the Department of Fish and Game studied the possible effects of the Box Canyon Project on fish and wildlife and presented its conclusions in a report entitled "The Effects of Box Canyon Dam and Reservoir on Fish and Wildlife Resources of the Upper Sacramento River Basin", March 1965. That report is available in limited numbers from both the Department of Water Resources and Department of Fish and Game libraries. Their report concludes in part:

> "Reservoir construction would greatly enhance the area's fisheries. The reservoir would be expected to produce several times more pounds of fish than do the streams that would be inundated, with no large increase in management costs. Angling use with the project would be many times that without the project. The project, also, would provide somewhat more favorable flows and improved temperatures in the Sacramento River below the dam, producing better trout habitat and more fish. Greater angler use would thereby be attracted, with some of the increase also attributable to use by anglers merely spreading out from camps they occupy at the reservoir."

The fisheries enhancement attributable to the project is measured in terms of the increase in fish production and fishable waters. The benefit from this enhancement is expressed by translating the increased fish production into increased angling activity and finally into economic values by assigning a dollar value to the angler-day. To evaluate the fisheries enhancement from the project, estimates of angling use were made for "with" and "without" project conditions throughout the period of economic analysis.

There are no anadromous fish in this area since the construction of Shasta Dam blocked migration above that point.

Reservoir Fishery

Streams within the reservoir area presently contain resident populations of rainbow and brown trout. Under project conditions these streams would be inundated and replaced by the reservoir trout fishery.

Fishing Use Without Project. In addition to the natural trout production of the streams within the reservoir area, the Department of Fish

and Game presently plants catchable-size trout from its Mt. Shasta fish hatchery. Present management calls for release of about 14,000 "catchables" annually in the project area, about 5,000 of which are placed above the reservoir site.

Surveys conducted by the Department of Fish and Game indicate that, with present management practices, 4,000 angler-days would be expended annually in the reservoir area in the year 1970 under "without" project conditions. As fishing pressure increases and management practices change, future "without" project use could be expected to increase to 31,000 angler days annually by the year 2020.

Fishing Use With Project. Box Canyon Reservoir could be described as a cold-water, natural trout producing lake. The saucer-like shape of the bottom of the reservoir would provide large areas of water less than 30 feet deep. These areas would be natural fish food-producing areas and, coupled with spawning gravels in the tributaries to the reservoir, would produce a reservoir highly suited to natural trout production. Operation of the reservoir as a stable pool would further enhance natural trout production because such operation would preserve all food-producing areas. Fish and Game officials believe that the natural trout production in the reservoir could be supplemented with hatchery-produced fingerlings to meet the initial fishing demand at no cost over that presently required for release of "catchables" in the area. It is estimated that with the reservoir being stocked with approximately 130,000 fingerlings annually (cost equal to present catchable planting program) the reservoir would produce about 30 pounds of fish per surface acre annually during the first decade. Then, as the initial fertility of the reservoir is reduced, the natural production would drop to about 20 pounds per surface acre and remain at that rate indefinitely.

At present, average fishing success is considered to be about two catchable-sized trout per angling day. In the future anglers will probably be satisfied with less. This lesser demand, coupled with the state trout planting program currently financed from fishing license fees, will allow the annual estimated angler-days at the reservoir to increase from a total of 38,000

initially to about 145,000 in the year 2020. Table 17 shows the estimated angler-days expected at the reservoir over the period of analysis. Figure 5 (see page 86) shows graphically the expected buildup of angling use "with" and "without" the project during the period of economic analysis.

TABLE 17

ESTIMATED ANNUAL ANGLER-DAYS AT BOX CANYON PROJECT
(in thousands)

Year	Without Project	With Project		Net Project Increase
		Reservoir	Downstream[1/]	
1970	4	38[2/]	0.6	34.6
1980	7	40	0.7	33.7
1990	10	57	0.8	47.8
2000	16	80	1.0	65.0
2010	22	110	1.1	89.1
2020	31	145	1.2	115.2

1/ Estimate presented is considered net; no estimate of total present or future use available.
2/ Reflects high initial use of the new reservoir followed by a leveling off period before a steady increase prevails.

Downstream Fishery

During water years varying from exceptionally dry to barely normal, the Sacramento River fishery below the dam would benefit from guaranteed release of good quality, temperature-controlled water. The fishery is of excellent quality at the present time. In fact, it is often described as one of the best in California. It is difficult to enhance an already excellent fishery.

In its study, the Department of Fish and Game attempted to determine the effect of the guaranteed release of good quality, temperature-controlled water. The Department believes that the period of good fish growth could be lengthened by at least 1 month, which would increase the number and size of fish produced in the downstream area. The estimate of increased angling due to the increase in fish production is from 600 angler-days in 1970 to 1,200 angler-days in 2020. These and intermediate periods are shown in Table 17.

A recommended reservoir water release schedule required for maintenance of the existing fishery and slight downstream enhancement is shown in the reservoir operation section of this chapter and in the Department of Fish and Game office report.

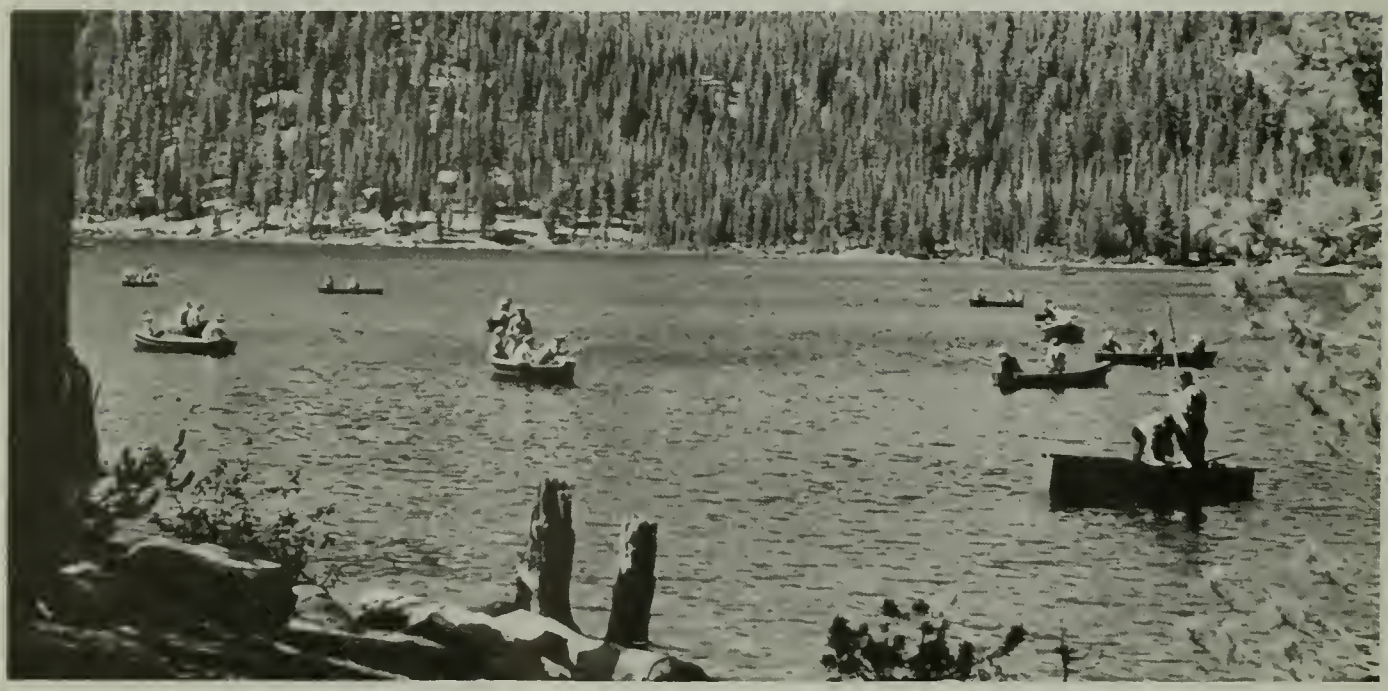
Fisheries Enhancement Benefits

Fisheries enhancement benefits from the project were determined by multiplying the number of net angler-days attributable to the project by the dollar value of a project visitor-day. The dollar value used was $2.30, the same as that for other recreation visitor-days. Table 18 presents a summary of the fisheries enhancement benefits by decades. The present worth value of total fisheries enhancement benefits from the project would be $2,500,000.

TABLE 18

FISHERIES ENHANCEMENT BENEFITS FROM BOX CANYON PROJECT

Decade	Net Angling-Days During Decade			Benefits	
	Reservoir	Downstream	Total	At $2.30 per Angler-Day	Present Worth
1971-1980	332,000	7,000	339,000	$ 780,000	$ 641,000
1981-1990	400,000	8,000	408,000	938,000	521,000
1991-2000	555,000	9,000	564,000	1,297,000	487,000
2001-2010	760,000	10,000	770,000	1,771,000	449,000
2011-2020	1,010,000	11,000	1,021,000	2,348,000	402,000
Total					$2,500,000



These pictures show some of the recreation activities that would be available at Box Canyon. Terrain and vegetative cover at Box Canyon are similar to those shown.

Recreation

The primary accomplishment of the Box Canyon Project would be to provide a reservoir with a near-constant water surface and a shoreline and surrounding area developed almost entirely for recreational activities. With the reservoir being operated only for recreation, fisheries enhancement, and flood control, a relatively stable water surface could be maintained during the entire summer recreation season. Figure 4 shows that reservoir drawdown during the recreation season is expected to be less than 3 feet during more than 88 percent of the time.

Recent studies of demand for outdoor recreation facilities in California show that there has been a sharp increase since World War II and that the increased demand is expected to continue for many years into the future. Data collected for this and previous studies show that many potential users of organized recreation areas in the Box Canyon vicinity presently are, and will continue to be, turned away unless more facilities are provided. This project would help fill the need for additional recreational facilities.

The environment of the Box Canyon area is extremely well suited to recreation. Surrounding the reservoir would be an area of Southern Siskiyou County noted for its spectacular scenery. The high snow-covered mountains, vast coniferous forests, mountain lakes, streams, and rivers support big game, upland game, and trout fisheries. Public enjoyment of the scenery and the attractive summer climate would be greatly enhanced by the reservoir recreation facilities and the opportunity for good fishing and water contact sports.

In a report titled "Mt. Shasta--Siskiyou Area Study", published in January 1962, the California Department of Parks and Recreation discusses the potential of the Box Canyon Project as a state park. The following statement about a Box Canyon Project was extracted from that report:

"High quality family camping, together with opportunities for enjoyment of the primitive mountain lands to the south and west in the Shasta-Trinity National Forest, are the principal recreational resources, and in themselves will justify the creation of a State [Park] Unit. [However], creation of a 500-acre recreational reservoir by the construction of a dam at Box Canyon would greatly increase the recreational potential of the area and lead to considerably heavier attendance."

Project recreation accomplishments are measured in terms of the increase of recreation use with the project over that without the project. Recreation benefits represent the economic value of this increased recreation use.

Estimates of present recreation use and future recreation demand at Box Canyon were made to determine benefits and to provide an estimate of required project features and a means of estimating costs. Although the Department of Parks and Recreation considers Box Canyon to have a high potential as a State Park, their present plans do not include a park unit at this site for many years. Therefore, estimates of recreation demand "without a project" assume that recreation facility development would continue to take place at the local level. Estimates of recreation demand "with a project" throughout the assumed 50-year economic life of the project are based on the following assumptions:

1. Recreation facilities required to supply the estimated demands would be installed.
2. The length of recreation season at full use level would be about 100 days.
3. Box Canyon Reservoir, with a surface area of about 430 acres and appropriate facilities to accommodate all types of anticipated uses, would be available.

Estimates of recreation use and recreation demand were made in terms of visitor-days. A visitor-day represents each day or significant portion of a day that each recreationist spends at the project site in connection with water-associated recreation activities. Recreation benefits were based upon net recreation use, which is the total project use minus the use that would have occurred without the project. Recreation benefits are computed by multiplying net visitor-days of use and the appropriate dollar value of a day's use.

To facilitate predictions of recreation demand, and costs of recreation facilities at Box Canyon, recreationists were classified either as campers, day-users, commercial visitors, or sightseers. However, in computing recreation benefits these recreationists were combined to determine the total number of visitor-days of recreation use. The following discussion concerns predictions of recreation demand created by each category.

Camping

Camping parties would stay overnight and thereby utilize project camping facilities. Camp units provided would be of state park standards, and each unit would consist generally of a fireplace, table, cupboard, parking area, and tent space. Water and sanitary facilities would be shared by several camp units.

The location of Box Canyon in relation to population centers, and the types of recreation activities suitable for development, indicate that camping would attract the largest number of recreationists to the area. The family campground would be a hub from which activities such as boating, fishing, swimming, and hiking would originate.

Camping Use Without Project. Mt. Shasta City owns property at the confluence of Wagon Creek and the Sacramento River where campers have used a slightly improved area. However, the area was virtually destroyed by the December 1964 flood and may not be restored. In the same vicinity, one privately owned campground of approximately eight units is open to the public but has not experienced heavy use. The total use of both areas before the flood was estimated to be about 2,000 visitor-days annually. Although other areas along the river are suitable for camp sites, only a very small amount of camping takes place because no facilities are available. Therefore, for the purpose of this study the amount of future camping use within the proposed project boundary was assumed to remain about the same unless a project offering good facilities were constructed at the Box Canyon site.

Camping Use With Project. The number of potential camper visitor-days at Box Canyon Reservoir was estimated by analyzing historical use data from MacArthur-Burney Falls State Park, since examination of this and other areas providing camp facilities in the region showed that this park was very similar to Box Canyon. In fact, the two areas would be almost identical in

The Box Canyon reservoir area (top photo) has almost the same topography and vegetation as Lake Britton, MacArthur-Burney Falls State Park.

elevation, temperature, topography, soil type, vegetative types, length of recreation season, proximity to a water body, and distance from large population centers. The MacArthur-Burney Falls State Park lies in Shasta County on State Highway 299, approximately 60 miles southeast of Mt. Shasta City. The photographs on the opposite page show the similarity of topography and vegetative types in the two areas.

Because of these similarities, it was assumed that, had the Box Canyon site been developed as proposed, potential camping use in the area during 1960 would have approximated camping demand at MacArthur-Burney Falls State Park during the same year. Estimates of camping demand at Box Canyon for the period from 1960 through 2020 therefore include the assumption that the 1960 camping demand at Box Canyon would be 45,000 visitor-days (the estimated 1960 camping use at MacArthur-Burney Falls State Park). Demand projections for years subsequent to 1960 were made by assuming that camping demands will increase in direct proportion to the expected increase in California population and, additionally, will reflect increased per capita participation in outdoor recreation. Such per capita participation in outdoor recreation was estimated from historical trends and is assumed in this report to increase throughout the study period at the rate of 2 percent of the initial use per year.

Recreation use during the first 10 years of project operation was modified in accordance with an analysis of recreation use data from Millerton State Park, which indicates that two-thirds of the use in the tenth year of project operation would occur in the fifth year. It was therefore assumed that during the first decade of operation, Box Canyon Reservoir would experience this same pattern of visitation. Consequently, in addition to the normal increase in use due to population and participation in outdoor recreation, the estimate of use during the first decade of operation was adjusted to correspond to the historical use pattern at Millerton State Park.

Day-Use

Day-users include fishermen, power-boat enthusiasts, and beach users. Although day-users do not stay overnight, many are picnickers who use available picnic facilities. The California Public Outdoor Recreation

Plan, published in 1960, reports that most day-use parties at recreation areas originate from within a maximum radius of 70 miles and an average of 35 miles from the recreation site, distances indicative of one-day excursions. By these figures, the counties of Siskiyou, Lassen, Modoc, Shasta, and Tehama lie within the Box Canyon day-use area. However, because Box Canyon is near Interstate Route 5, this radius would be greatly expanded. Many vacationers from distant areas would picnic, swim, and fish at Box Canyon.

Day-Use Without Project. Present day-use within the project area consists almost entirely of stream fishing. There is very little picnicking and no boating. Youngsters from Mt. Shasta City swim in the river above the mouth of Box Canyon and in a farm pond in the proposed reservoir area. However, total use of both of these swimming areas is relatively small. Sport fishing, although generally considered day-use, is considered separately to facilitate determination of the project fisheries enhancement benefits.

Surveys conducted in the project area indicate that present annual day-use is about 3,000 visitor-days. Using this estimate as a beginning point, future day-use without a reservoir was estimated for the period from 1960 through 2020. Projections of use were made by assuming that use would increase in direct proportion to the expected increase in population of the counties of Siskiyou, Lassen, Modoc, Shasta, and Tehama, and be further increased by the annual rate of increase in per capita participation in outdoor recreation which was developed for camping use projections.

Day-Use With Project. Recreation facilities and a reservoir with a stable water surface at Box Canyon would provide many opportunities for day-use activities which do not presently exist in the area. They would also enhance further those activities presently enjoyed. Good swimming, beaches, boating areas, a boat launching ramp, picnic facilities, and an excellent reservoir fishery would become available under project conditions.

Following analysis of both population distribution and the results of a recreation survey conducted at Dwinnell Reservoir in Shasta Valley in 1958, potential day-use for 1960 under project conditions at Box Canyon was estimated at 13,000 visitor-days. The reasonableness of this estimate was verified by comparing it to the visitor-days of use experienced by several newly developed reservoirs.

The area within 15 miles of the project includes the cities of Mt. Shasta, Dunsmuir, McCloud, and Weed, and has a total population of about 14,000 people. An annual day-use rate of one visit per capita from this combined population would result in 14,000 visitor-days of day-use at Box Canyon. The estimate of 13,000 visitor-days for 1960, if a reservoir had been available at Box Canyon, appears conservative.

The 1960 estimated day-use of the Box Canyon area with a project was used as a starting point to estimate day-use to the year 2020. Such estimates used the same method of increasing day-use in proportion to the population increase of Siskiyou and neighboring counties, and in proportion to the increase in per capita participation in outdoor recreation.

Sightseeing

Sightseers would consist of visitors who come expressly to view the project, but who would be in the area for only a part of a visitor-day. Since these people would make use of overlook vistas, parking areas, and sanitary facilities, in addition to the intangible benefits from the project, they are included as project recreation visitors.

An average of 27 percent of the recreation visitors to 18 projects reported in the 1958 summation of U. S. Bureau of Reclamation recreation data were sightseers. In 1959, an average of 28 percent of the recreation visitors at Friant, Folsom, Sly Park, Stony Gorge, and Cachuma Reservoirs were sightseers, according to additional data supplied by the Bureau. The "Mt. Shasta--Siskiyou Area Study", published in January 1962 by the California Division of Beaches and Parks, states that sightseers represent approximately 50 percent of the recreationists in District I, which includes the counties of Shasta, Siskiyou, Trinity, Modoc, Lassen, Del Norte, Humboldt, and Tehama, as well as part of Mendocino County.

Sightseer use at Box Canyon, however, probably will most nearly approximate the U. S. Bureau of Reclamation averages at reservoir projects because Box Canyon will more nearly represent this type of recreation area than those with outstanding natural attractions such as MacArthur-Burney Falls or Castle Crags State Parks in Shasta County. Therefore, it was estimated that in addition to the campers and day-users, sightseers numbering 25 percent of the total recreation use would visit Box Canyon Reservoir.

However, only one-fourth of these sightseers, or about 7.5 percent of the total recreation use, would stay in the project area long enough to be counted as a recreation visitor day. These are considered to be net visitor days since present sightseeing use is negligible.

Visitors Using Commercial Facilities

Many people enjoy being in the outdoors and participating in outdoor activities but are either not physically able or are not inclined to "rough-it" by spending the night in a campsite. Although they would like to participate in water-associated activities such as boating, fishing, swimming, or hiking along the water's edge, they would do so only if more sophisticated facilities such as lodges, cabins, and restaurants were available at or near the reservoir. The Department of Parks and Recreation is finding in its operation of the State Park System that a demand for this type of use is increasing. Consequently, it is attempting to fill this demand by allowing privately financed commercial developments within state recreation areas. These establishments are, of course, subject to control and regulation by the State Park authorities.

The number of commercial visitor-days attributable to the project was estimated by considering the number of user-days at a commercial facility in the same location without the water project and the number which would use the same facility with the project in existence. The difference in use is considered net use attributable to the existence of the project.

The total commercial visitor-use at the Box Canyon Project was estimated by investigating the use at existing recreation areas which include a similar commercial development. As an example, at Pfeiffer-Big Sur State Park, which has a concession offering lodge, cabins, gift shop, restaurant, groceries, and other commercial services, records indicate that 16 percent of the park attendance occurs because of the combination State Park and commercial facilities. The net commercial visitor-use at Box Canyon was estimated to be about 10 percent of the use predicted for all project activities, or about 14,000 visitor-days annually at the beginning of project operation.

To meet the demand of the "commercial visitor", a portion of the project lands has been set aside for commercial development. This area is shown on Plate 4. The type and extent of this development has not been precisely

determined, as it is intended that commercial facilities would be developed by private financing in accordance with the demand. (However, the expected initial commercial visitor use would require a lodge with approximately 15 overnight units and a food service and boat rental facility. These facilities would be expanded as the demand increased.)

Since these users do not utilize the camping facilities provided at the project and since costs of private facilities are not shown, commercial users were considered equivalent to day-users in the project analysis.

Summary of Recreation Use

Table 19 includes a summary of estimated recreation use during the period of economic analysis. The table shows the use with and without the project for two categories of visitor-use: general recreationists and anglers. Figure 5 shows graphically the expected buildup of recreation use "with" and "without" the project during the period of economic analysis.

TABLE 19

ESTIMATED RECREATION AND ANGLING USE AT THE BOX CANYON PROJECT
(In 1,000 visitor-days annually)

NOTE: Increased angling downstream from dam is not included

Year	Project Year	Use Without Project: Recreation	Use Without Project: Angling [1]	Use Without Project: Total	Use With Project: Recreation: Total	Use With Project: Recreation: Net	Use With Project: Angling: Total	Use With Project: Angling: Net	Use With Project: Total: Net	Use With Project: Total: Project Use
1970	0	5	4	9	78	73	38	34	107	116
1st Decade		66	54	120	1,144	1,078	386	332	1,410	1,530
1980	10	8	7	15	132	124	40	33	157	172
2nd Decade		105	85	190	1,605	1,500	485	400	1,900	2,090
1990	20	13	10	23	189	176	57	47	223	246
3rd Decade		160	130	290	2,275	2,115	685	555	2,670	2,960
2000	30	19	16	35	266	247	80	64	311	346
4th Decade		230	190	420	3,110	2,880	950	760	3,640	4,060
2010	40	27	22	49	356	329	110	88	417	466
5th Decade		325	260	585	4,170	3,845	1,270	1,010	4,855	5,440
2020	50	37	31	68	477	440	145	114	554	622

[1] Assumed to be 45 percent of total use without project within the proposed project boundary.

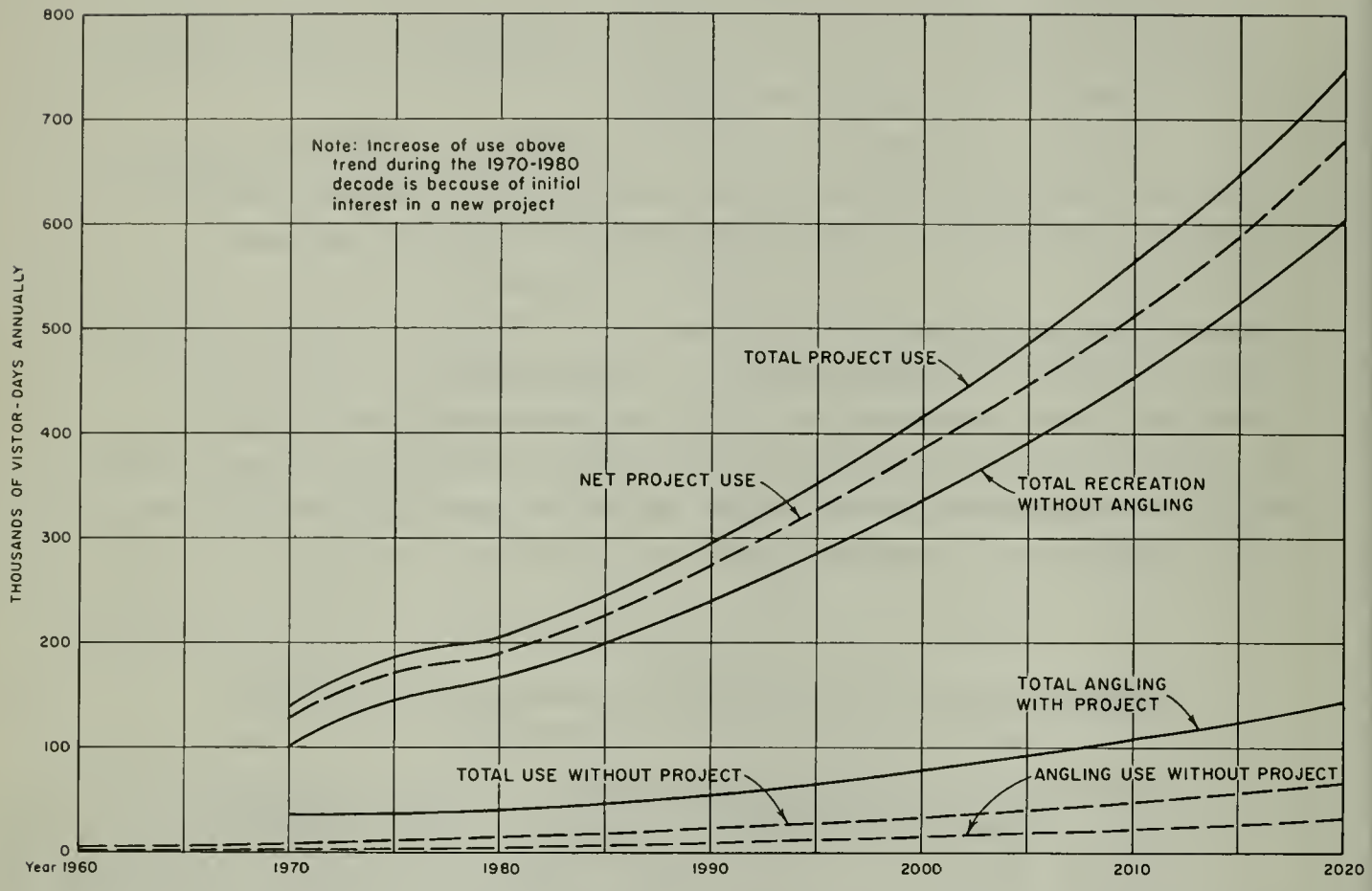


Figure 5. ESTIMATED RESERVOIR RECREATION USE AT BOX CANYON PROJECT

Recreation Benefits

Recreation benefits of the project were determined by multiplying the number of net recreation visitor-days attributable to the project and the dollar value of a visitor-day. The dollar value of a visitor-day of recreation use at Box Canyon Reservoir would be $2.30.

It is believed that the time most sightseers spend at the project would not constitute a sufficient part of a day to justify inclusion of a full visitor-day's benefit. Therefore, only those sightseers who spend a substantial part of a day within the project area are included in the computation of total visitor-days at Box Canyon Reservoir.

The "Consumer's Surplus" method, described in Appendix A, Department of Water Resources Bulletin No. 59-2, "Investigation of Upper Feather River Basin Development", was used to obtain the dollar value of a visitor-day of recreation use. As applied to recreation, a consumer's surplus occurs when some people are willing to pay more than others for the same recreational pleasure. To compute the size of this difference or surplus, travel costs are assigned to expected visitor origins. The difference between the median travel cost and the cost below which 90 percent of the visitor-day expenses occur constitutes the consumer's surplus or visitor-day value.

Estimates of travel cost per visitor-day were determined from data gathered during field investigation at MacArthur-Burney Falls and Castle Crags State Parks. Such data included the number of people in each party, the area of origin of each part, and the number of days each party spent in the area. Table 20 shows the estimated origin distribution of visitors to the Box Canyon Project. A figure of 7.5 cents per mile was used as the average automobile travel cost.

TABLE 20

ORIGIN OF BOX CANYON PROJECT RECREATION VISITORS

Distance of Origin From Box Canyon (miles)	Percent of Total Project Recreation Visitors
0 to 100	10
100 to 200	7
200 to 300	35
300 to 400	11
400 to 500	2
500 to 600	12
600 to 700	19
700 to 800	3
Total	100

Project recreation benefits were computed first as the totals accuring during each decade of a 50-year repayment period, using the projected net visitor-days previously discussed and the value of $2.30 per visitor-day for all recreationists. The total benefits for each decade were then reduced to present worth values at the beginning of the project to express benefits in the same financial terms as total costs. A summary of this procedure presented in Table 21 shows that the present worth value of total recreation benefits (excluding fisheries enhancement) at the proposed Box Canyon Reservoir would be $8,971,000.

TABLE 21

RECREATION BENEFITS FROM BOX CANYON PROJECT

Decade	Net Visitor-Days	Benefits	
		At $2.30 Per Visitor-Day	Present Worth
1971-1980	1,078,000	$2,479,000	2,037,000
1981-1990	1,500,000	3,450,000	1,916,000
1991-2000	2,115,000	4,865,000	1,825,000
2001-2010	2,880,000	6,624,000	1,679,000
2011-2020	3,845,000	8,844,000	1,514,000
Total			8,971,000

Flood Control

The purpose of flood control was considered at Box Canyon Reservoir during the study reported on in Department of Water Resources Bulletin No. 100. In that report it was concluded that benefits to be derived from flood control were too low to warrant inclusion of flood control works.

However, very little information on peak flood flows and related flood damages was available for use during that study. Since that study was made two floods have occurred, a minor one in October 1962 and a major one in December 1964. Significant hydrologic data were collected and up-to-date flood damage estimates were made from these floods. This information was used to re-evaluate the purpose of flood control at Box Canyon Reservoir.

The Flood Problem

Property located in a 17-mile reach of the Sacramento River canyon between Box Canyon Dam site and the town of Castella is frequently damaged by flooding. Dunsmuir, located about 8 miles downstream from the Box Canyon damsite, is near the center of this flood damage area. When the river overflows its banks in Dunsmuir, private residences, commercial establishments, streets, bridges, sewers, and water lines are damaged, and the usual problems associated with repair and cleanup caused by flood waters are experienced. No loss of life has been reported due to past floods, but when bridges are washed out and homes are flooded, the threat to life is always a possibility.

Upstream and downstream from Dunsmuir the Southern Pacific Railroad winds its way along the river. The tracks cross back and forth over the stream to take advantage of the best route through the narrow, constricted canyon. During extremely large floods such as those of 1940, 1955, and 1964, the railroad generally experiences track washouts and damage to fills and bridges.

The flood of October 1962 caused very minor damage. The peak flow at the stream gaging station located about 6.5 miles upstream from Dunsmuir (129-square-mile drainage area) was recorded as 9,500 second-feet. The peak flow at Dunsmuir (160-square-mile drainage area) was estimated at 10,500 second-feet. Based on this information the nondamaging river channel capacity at Dunsmuir is estimated at 9,000 second-feet. In other words, if the flow of the Sacramento River at Dunsmuir could be kept below 9,000 second-feet there

would be no significant flood damage from the river in the reach being considered, barring, of course, unforeseen occurrences such as log jams, slides, and levee failures.

Flood Damage

The benefits from flood protection are expressed in terms of (1) the estimated average annual flood damage which would be prevented by the project and (2) the increase in utility of land protected from future flooding. To determine these benefits, estimates of historical and future flood damages were made. These estimates are discussed in the following paragraphs.

Estimated Historical Damage. A survey of historical flood damage was made to aid in estimating average annual flood damages.

In the last 25 years, five floods have occurred for which some damage estimates were available. These floods occurred in February 1940, December 1955, February 1958, October 1962, and December 1964. Reliable estimates of damages were available for the four most recent floods but information concerning the 1940 flood was sketchy.

Table 22 presents a summary of estimated damages to residential areas, commercial establishments, agriculture, industry, public utilities, and public works in the flood damage area during these five floods. Estimates of historical damage were updated to the present dollar value by using the Engineering News Record composite cost index.

TABLE 22

ESTIMATED HISTORICAL SACRAMENTO RIVER
FLOOD DAMAGE BOX CANYON DAMSITE--CASTELLA AREA

Date	Estimated Peak Flow at Dunsmuir, (second-feet)	Flood Damages Updated to 1965
February 1940	22,000	$230,000
December 1955	14,500	70,000
February 1958	13,000	40,000
October 1962	10,500	10,000
December 1964	17,500	400,000 1/

1/ Damages are probably greater than usual for this flow because three highway bridges were washed out.

Data from Table 22 were used to construct a flood damage curve showing expected damage for any particular flow under preproject conditions.

Estimated Future Damage. Future flood occurrence was based on a statistical analysis of the frequency of past flooding during the period 1920 through 1964. Table 23 shows the probability of exceedance, or the percent of time that annual flood peaks are expected to exceed various flood magnitudes ranging from 1,000 to 40,000 second-feet. This table also shows the estimated monetary damages obtained from the flood damage curve for floods of various magnitudes.

The total average annual future flood damage would be $32,600. This amount was used as the total maximum benefit if all future flooding were prevented in this area. No increase in utility of the floodplain was considered since almost all of the floodplain lands suitable for occupancy are presently developed. Therefore, no large increase in development could occur if flood protection were provided. However, it is realized that some of the low cost housing now existing along the river would be replaced with more expensive homes if adequate flood protection were provided.

Analysis of the Flood Problem

Economic justification of including flood protection works as a purpose in the Box Canyon Project was determined by comparing the costs of providing protection with the benefits of flood damages prevented. Flood protection is a matter of degree, since rarely is absolute protection from flooding achieved by any flood control works. The problem, then, becomes one of finding the point at which the greatest amount of protection can be achieved while still maintaining an excess of benefits over costs. To find this point, costs and benefits were examined at many levels of flood protection.

Costs of Flood Control. Control of floods with a reservoir is accomplished by reserving during the flood season a portion of the reservoir storage capacity for flood water. Following the flood threat, the water is released in a nondamaging flow until the proper flood control reservation is again achieved.

At Box Canyon Reservoir the cost of including flood control as a purpose would be (1) the increased cost of enlarging the outlet works above

TABLE 23

ESTIMATED SACRAMENTO RIVER FLOOD DAMAGE
BOX CANYON DAMSITE--CASTELLA AREA

Peak Flow at Dunsmuir (second-feet)	Exceedence Percentage	Difference in Exceedence Percentage	Midpoint of Flow (second-feet)	Damages	Average Annual Damage
1,000	100				
		79	5,000	$ 0	$ 0
9,000	21				
		3	9,500	4,000	100
10,000	18				
		6	11,000	16,000	1,000
12,000	12				
		3.5	13,000	40,000	1,400
14,000	8.5				
		2.5	15,000	90,000	2,300
16,000	6				
		2	17,000	220,000	4,400
18,000	4				
		1.5	19,000	450,000	6,800
20,000	2.5				
		1.3	22,000	610,000	8,000
24,000	1.2				
		0.8	26,000	710,000	5,700
30,000	0.4				
		0.25	32,000	800,000	2,000
34,000	0.15				
		0.10	37,000	850,000	900
40,000					
	0.05				
Total Average Annual Damage					$32,600

that required for recreation and fisheries enhancement, and (2) that portion of the dam and reservoir cost assigned to flood control because of the required flood storage reservation. For this analysis, the cost of flood storage reservation was estimated as the cost of planting catchable-size trout to replace the loss in natural production due to the fluctuating reservoir level. Increased cost of the outlet works for water releases up to 2,000 second-feet includes the difference between the cost of a steel liner in the 7-foot-diameter diversion conduit and the 3-foot-diameter outlet pipe needed if flood control is not provided, plus the additional cost of larger control valves. To obtain releases greater than 2,000 second-feet the total outlet structure would have to be enlarged and the cost would increase greatly.

Table 24 shows estimated costs of flood control for various combinations of flood storage reservation and outlet works capacities.

TABLE 24

COMPARISON OF FLOOD CONTROL COSTS AND BENEFITS

Flood Storage Reservation (acre-feet)	Outlet Works Capacity (second-feet)	Estimated Cost of Flood Control Works	Estimated Present Worth Value of Benefits	Net Flood Control Benefits
0	300	$ 0	$100,000	$100,000
	2,000	250,000	100,000	*
	4,000	860,000	100,000	*
	6,000	1,400,000	100,000	*
10,000	300	60,000	100,000	40,000
	2,000	310,000	160,000	*
	4,000	920,000	270,000	*
	6,000	1,460,000	430,000	*
15,000	300	100,000	100,000	0
	2,000	350,000	230,000	*
	4,000	960,000	310,000	*
	6,000	1,500,000	520,000	*

* Costs are greater than benefits

Benefits from Flood Control. To estimate the flood control benefits from Box Canyon Reservoir, floods with exceedence percentages of 1, 2, 5, and 10 were routed through the reservoir using various combinations of outlet works capacities and flood storage reservations. From these studies, the reduction in flood frequencies, and in turn the flood control benefits, were determined. Benefits from the combinations investigated are shown in Table 24.

Conclusions

Table 24 shows that the greatest net flood control benefit would be realized by not including specific works for flood control. This happens for several reasons:

1. Average annual flood damages, and in turn flood benefits, are relatively small.
2. Specific flood control works are very costly.
3. The volume of flood water is large in relation to the storage which could be provided. For instance, the maximum 2-day volume of the December 1964 flood was about 40,000 acre-feet at the damsite. Consequently, the storage which could be afforded by Box Canyon Reservoir would not be very effective.
4. The area of greatest flood damage is several miles downstream from the Box Canyon Reservoir site. There is, therefore, considerable inflow between the damsite and the damage areas which cannot be controlled.

For the above reasons it is concluded that inclusion of large flood control storage and costly outlet works would provide only minor flood protection below the Box Canyon Project and, therefore, should not be included in the project. However, the reservoir would often be drawn down about 2,000 acre-feet below normal pool elevation by October 1, and to guarantee this amount of reservation in the reservoir each year would not noticeably decrease the recreation or fisheries enhancement benefits. It is therefore concluded that 2,000 acre-feet of flood storage reservation should be maintained at Box Canyon Reservoir between October 10 and March 15 whenever it is physically possible. Under this operation the reservoir would fill every year and would remain full or nearly full during the entire recreation season.

The combination of the 2,000 acre-feet of flood storage reservation and surcharge storage (the amount of reservoir storage above the spillway lip when the spillway is discharging) would provide some reduction in flood peaks throughout the damage area. The benefit from the reduction in flooding is estimated to be about $5,000 annually or slightly over $100,000 on a present worth basis.

To give an indication of the actual physical benefit from this type of operation, the December 1964 flood was routed through the reservoir and the flood peak at Dunsmuir was estimated. Without the project the record shows that the Sacramento River crested at the Southern Pacific gage in Dunsmuir at about 13.5 feet with an estimated flow of 17,500 second-feet. With the project operated as outlined previously it is estimated that the flow would have been reduced to 15,000 second-feet and the corresponding flood crest would have been 12.5 feet. Although this is not a large reduction, the remaining flow would be about the same magnitude as the 1955 flood, which did not flood the main residential area nor wash out any bridges, and it did much less damage to the railroad. In addition, the reservoir would have reduced the October 1962 flood to nondamaging flows and would have stopped most of the logs and debris which caused major damage to bridges and water and sewer line crossings in Dunsmuir during the 1964 flood.

To achieve greater protection in Dunsmuir, study should be given to adding to the existing revetments, levees, and bank protection works. Much of the past flooding is due to the channel becoming choked with brush, gravel bars, and debris. A channel improvement and maintenance program should be adopted to insure that a maximum carrying capacity of the stream channel is available at all times.

A study of the floodplain use should also be undertaken. This study should establish areas of restricted use within the floodplain to prevent further encroachment upon lands subject to frequent flooding. It should always be borne in mind that flood protection is only a matter of degree and that eventual flooding will occur in the floodplain.

Box Canyon Reservoir, coupled with an active river channel improvement and maintenance program in and around Dunsmuir and a floodplain regulation program, should reduce the flood threat of the Sacramento River in the Box Canyon

Damsite -- Castella area to a degree which would be much more tolerable to present and future generations.

Summary of Primary Project Benefits

A summary of the estimated primary project benefits during the 50-year period of economic analysis is presented in Table 25.

TABLE 25

SUMMARY OF BOX CANYON PROJECT PRIMARY BENEFITS

Project Purpose	Present Worth of Total Benefits	Average Annual Equivalent Benefits
Recreation	$8,971,000	$418,000
Fisheries Enhancement	2,500,000	116,000
Flood Control	100,000	5,000
Total	$11,571,000	$539,000

Secondary and Intangible Benefits

Economic justification of the Box Canyon Project is based only on its primary benefits; such secondary benefits as increased property values, new capital induced into the community, and increased local net income are not included. Furthermore, intangible aesthetic and social benefits that would be created by construction of the Box Canyon Project, but which do not lend themselves to measurement in monetary terms, are also not included.

Although secondary and intangible benefits are not considered in economic analyses, they are important factors to consider in establishing the need for the project. For instance, a study of the economic value of state

parks in Oregon revealed that park visitors stay longer in a general area because of the presence of a park. In the southern Siskiyou and Northern Shasta County areas surrounding Box Canyon Reservoir, such an increased length of stay would mean greater expenditures by the recreationists. The needs of recreationists for goods and services in this general area would increase sales at present business establishments, create the need for new businesses, and stimulate the investment of new capital in the community. Also, the increased value of private property in the vicinity of Box Canyon would create an assessed valuation greater than that which exists under conditions without the project.

The intangible benefits which would be derived from Box Canyon Reservoir have been stressed by recreation and park planners who have visited the project area and praised the high aesthetic quality of the setting.

Although these benefits are not considered by the State as direct benefits, they are nonetheless very real to the economy of the Weed--Mt. Shasta City--Dunsmuir Area.

CHAPTER 6. FEASIBILITY DETERMINATION

For a project to be feasible for development it is generally considered that it must possess the three following qualifications: (1) engineering feasibility, (2) economic justification, and (3) financial feasibility. The purpose of this study was to determine if the Box Canyon Project possessed these qualifications. In this chapter each qualification is defined and the methods used in determining project qualification are discussed.

Engineering Feasibility

In broad, general terms a project is considered to possess engineering feasibility if it can be safely constructed by accepted techniques at a reasonable cost. The main features of this project which were examined for engineering feasibility were the dam and reservoir.

For the dam and reservoir to be considered engineeringly feasible the following conditions must be met:

1. The water supply must be adequate in quantity and quality to meet the expressed purposes of the project.
2. The dam and reservoir sites must be geologically suitable.
3. Construction possibilities must be such that the structures will serve their purposes safely and efficiently.
4. Construction must be possible with available materials and accepted techniques at reasonable costs.

Each of these conditions were examined during this study.

Facts about present and expected future water supply presented in Chapter 3 demonstrate that there would be an adequate water supply available to meet the present and future project demands.

Interpretation of results of subsurface geologic exploration conducted at the dam and reservoir sites shows that the sites selected would be geologically suitable for the proposed structures.

Designs for a dam and its appurtenant structures have been prepared and reviewed. It is believed that structures similar to those presented could be constructed and that they would safely and efficiently serve the project purposes.

Materials proposed for use in construction of the structures are available locally and could be used, by employing accepted design and construction techniques, to construct the facilities at a reasonable cost.

Based on these studies it is concluded that the Box Canyon Project, including the dam, reservoir, and appurtenant structures, meets all of the conditions of engineering feasibility outlined above and that the project is therefore engineeringly feasible.

Economic Justification

Economic justification requires that the economic benefits exceed the economic cost of the project. Economic justification is generally expressed as a ratio of benefits to costs and is commonly called the benefit-cost ratio. Since a major portion of the project cost (construction costs) generally occurs prior to the beginning of project operation and the project benefits accrue over some period of time following project construction, a common period for economic analysis must be selected upon which a comparison of costs and benefits may be made on a common time basis. For analysis of this project a period of 50 years following initial project construction was selected. Project construction was assumed to be completed in 1970. An interest rate of 4 percent per year was used to discount future expenditures to a present-worth value. This is in accordance with the method used in analyzing projects to determine their eligibility for grants of money under the Davis-Grunsky Act.*

The following information on project benefits and costs is taken from the summary of costs and benefits in Chapters 4 and 5. The present-worth value of total project benefits throughout the 50-year period of analysis (1970-2020) was estimated to be $11,571,000. The total cost of the project, based on 1964 price levels, includes initial construction costs and the present

* The Davis-Grunsky Act is a part of the California Water Code which provides state financial assistance for local water projects.

worth value of future expenditures for additions and for operation, maintenance, and replacement. This cost was estimated to be $11,076,000. The resulting benefit-cost ratio, 1.04 to 1.0, indicates economic justification.

As previously noted, secondary benefits, although providing a very important contribution to the local economy, were not included in evaluating project benefits. Although the benefit-cost ratio based on primary benefits alone is not high, it is believed that the secondary benefits which would accrue to Siskiyou County, and to the Mt. Shasta City--Dunsmuir area in particular, make this project much more desirable than the above benefit-cost ratio indicates.

Financial Feasibility

A project is considered to be financially feasible if funds for construction and operation of the project are available, and further, that if these funds must be repaid, the revenues from the project will provide for repayment at the stipulated interest rate.

The cost of project construction and operation was estimated and allocated to the recreation and fisheries enhancement purposes, possible sources of funds for construction and operation of the project were studied, and a plan for financing construction and operation of the project was formulated. A discussion of these phases of determining the financial feasibility of the project is presented in the following sections.

Allocation of Project Costs

Cost allocation is the process of apportioning costs of a multiple-purpose project equitably among the various purposes served by the project. This is an essential step in the economic evaluation process since it provides the basis for determining the amount to be paid by each of the project beneficiaries for the various project services. The allocation embraces all project costs, including costs of construction, operation, maintenance, and replacement. The concept of cost allocation assumes that the total cost of combining several purposes in a comprehensive project is substantially less than the sum of the costs of separate projects provided for each purpose, and that the savings derived through use of multiple-purpose structures should be shared by all purposes.

In the cost allocation for this project no project costs were allocated to flood control. The two main reasons for this procedure are: (1) less than 1 percent of the project benefits are from flood control, and (2) no specific project costs were attributed to flood control. Therefore, since about 99 percent of the benefits are due to recreation and fisheries enhancement, and since the policy of the U.S. Corps of Engineers is not to participate financially in a project that does not include specific flood control features, it was decided that the project costs should be apportioned only between the primary purposes of recreation and fisheries enhancement. Consequently, the following cost allocation applies only to these two purposes.

While there are several available methods of allocating costs of a project, the separable costs--remaining benefits method is generally considered to be superior. Consequently, this method, which has been recommended by the Federal Interagency Committee on Water Resources for general use in allocating costs of federal multiple-purpose river basin projects, is used by the Department of Water Resources. Briefly, the separable costs--remaining benefits method involves:

1. Determination of justifiable costs through evaluation of the benefits accruing to each purpose, such benefits limited by the least costly alternative.
2. Determination of the separable costs of each project.
3. Subtraction of the separable costs from the justifiable costs.
4. Assigning each purpose a share of the residual or remaining joint costs in proportion to the remaining justifiable costs.

Alternative Costs. In the separable costs--remaining benefits method of cost allocation, the benefits for a particular purpose are limited to the cost of the least costly single-purpose alternative project which would provide equivalent benefits for that purpose. A brief description of the single-purpose projects that were formulated as alternatives to the Box Canyon Project, and the estimated cost of each, is presented in Table 26.

Separable Costs. The separable cost for a given project purpose is the difference between the cost of the multiple-purpose project and the cost of the project with the purpose omitted. Table 27 shows the separable

costs estimated for each project purpose and gives a brief description of how they were determined.

TABLE 26

SUMMARY OF SINGLE-PURPOSE ALTERNATIVE PROJECT COSTS FOR BOX CANYON PROJECT COST ALLOCATION
(in thousands of dollars)

Purpose	General Project Description	Costs			Present Worth of Benefits	Benefit-Cost Ratio
		Initial Capital	Present Worth of Future Annual 1/	Total Present Worth		
Recreation	Dam height, 209 feet; reservoir storage, 26,000 AF; 1,890 acres of project lands; recreation facilities and operation costs at 78% of multiple-purpose project; water supply and sanitary facilities unchanged; no change in deer range improvement.	6,220	3,610	9,830	9,071	0.9
Fisheries Enhancement	Dam height, 209 feet; reservoir storage, 26,000 AF; 1,350 acres of project lands; recreation facilities and operation costs at 22% of multiple-purpose project; water supply and sanitary facilities at one-half of multiple-purpose project; no change in deer range improvement.	5,290	1,220	6,510	2,500	0.4

1/ Future annual costs represent the average annual equivalent of total future project expenditures for installation of future recreation facilities, and project operation, maintenance and replacement.

TABLE 27

SUMMARY OF SEPARABLE COSTS FOR BOX CANYON PROJECT COST ALLOCATION
(in thousands of dollars)

Purpose	General Description	Costs			Separable Cost	Benefits
		Initial Capital	Present Worth of Future Annual 1/	Total Present Worth		
Multiple-purpose	Dam height, 209 feet; reservoir storage, 26,000 AF. Recreation and other facilities as described in Chapter 4.	6,511	4,565	11,076	-	11,571
Recreation	The project becomes a single-purpose fisheries enhancement project when the recreation purpose is omitted.	5,290	1,220	6,510	4,566	9,071
Fisheries Enhancement	The project becomes a single-purpose recreation project when the fisheries enhancement purpose is omitted.	6,220	3,610	9,830	1,246	2,500

1/ Future annual costs represent the average annual equivalent of total future project expenditures for installation of future recreation facilities, and project operation, maintenance and replacement.

Cost Allocation. Initial project construction costs and future expenditures for additions, operation, maintenance, and replacement were allocated among the project purposes. The allocation is presented in Table 28. Interest during construction was not included as a project cost since it was assumed that the project will be constructed with state and federal grants.

TABLE 28

BOX CANYON PROJECT COST ALLOCATION
(In thousands of dollars)

(Expressed as present worth values)

Item	Recreation	Fisheries Enhancement	Total
Benefits	$ 8,970	$ 2,500	$ 11,470
Alternative costs	9,510	6,190	---
Justifiable costs	8,970	2,500	11,470
Separable costs	4,565	1,245	5,810
a. Initial capital	1,220	290	1,510
b. Future annual	3,345	955	4,300
Remaining justifiable costs	4,405	1,255	5,660
Distribution of remaining justifiable costs	78%	22%	100%
Total project cost[1/]			10,915
Total separable cost			5,810
Total remaining joint costs			5,105
Allocated remaining joint costs[2/]	3,995	1,110	5,105
a. Initial capital	3,790	1,050	4,840
b. Future annual	205	60	265
Total allocated costs[3/]	8,560	2,355	10,915
a. Initial capital	5,010	1,040	6,350
b. Future annual	3,550	1,015	4,565

Note: Initial capital costs are construction costs and expenditures required to put the project into its first year of operation.

Future annual costs are estimated costs of operation, maintenance, and replacement, and future costs of installation of recreation facilities.

1/ Does not include interest during construction since it is assumed the project will be constructed with state and federal grants.

2/ These costs are allocated in accordance with the percentage distribution of remaining justifiable costs.

3/ Summation of separable costs and allocated remaining joint costs.

Possible Sources of Construction Funds

Funds for construction of the Box Canyon Project could come from a variety of sources. Among these are (1) state financing through grants and loans under provisions of the Davis-Grunsky Act, (2) federal financing under the Land and Water Conservation Fund Act of 1965, or the Public Works and Economic Development Act of 1965, and (3) local financing through the sale of bonds.

It is not within the scope of this report, and it is not possible at this time, to lay out a program showing all possible means of financing the project. However, it is desirable that the most apparent known sources be pointed out to aid the local agency taking responsibility for the project to decide the best way to proceed toward getting the project under construction.

At the present time neither the federal nor state governments have programs through which complete financing would be possible. However, both agencies have programs which could provide a part of the project costs in the form of recreation or fisheries enhancement grants. In addition, the federal government, through the U. S. Army Corps of Engineers, can make grants for flood control, and the state, through provisions of the Davis-Grunsky Act, can make loans to local agencies. The Siskiyou County Flood Control and Water Conservation District has expressed an active interest in constructing the project. The District has filed a preliminary request for determination of eligibility for a grant of state funds through the Davis-Grunsky Act. The Mt. Shasta Recreation and Park District had been suggested as another possible constructor of the project. Either of the agencies could probably qualify for state and federal grants.

The remainder of this section is devoted to pointing out possible sources of construction funds available to a qualified agency, such as the Siskiyou County Flood Control and Water Conservation District, and to determining the estimated amounts available from each source.

State Funds through the Davis-Grunsky Act. The Davis-Grunsky Act is incorporated in the California Water Code beginning with Section 12880. This act provides state financial assistance in the form of grants and loans to qualified public agencies for water development projects. The Siskiyou County Flood Control and Water Conservation District has been adjudged a qualified agency.

The California Legislature, through Chapter Nos. 124 and 478 of the 1965 legislative session, has authorized the Department of Water Resources to make a grant of up to $4.8 million to either the Siskiyou County Flood Control and Water Conservation District or the Mt. Shasta Recreation and Park District. This grant would be of such amount as may be determined by the Department for Box Canyon Project costs allocated to recreation and fish and wildlife enhancement, within the established provisions of the Davis-Grunsky Act, but not exceeding the authorized $4,800,000.

It was determined in accordance with provisions of the Act, that the total allowable Davis-Grunsky grant for construction of the project would be $4,117,000. The method used in determining the allowable grant is presented in Table 29.

Federal Funds. Various sources of federal funds may be available to help finance construction of the Box Canyon Project. Two of the most promising are discussed briefly below:

(1) Public Law 88-578, known as the Land and Water Conservation Fund Act of 1965, provides funds for and authorizes federal assistance to the states in planning, acquisition, and development of needed land and water areas and facilities for outdoor recreation. These funds will be provided to the states on a matching basis whereby not more than 50 percent of the cost of the recreation development may be borne by federal funds.

Interpretation of the law indicates that any federal funds made available to the State by this act could be used by the public agency constructing the project. The law specifically provides:

> "If consistent with an approved project, funds may be transferred by the State to a public subdivision, or other public agency."

(2) Public Law 89-136, known as the Public Works and Economic Development Act of 1965, provides federal grants and loans to aid planning and financing construction of public works projects for areas of high unemployment.

The agency concerned with funding construction costs of this project should follow closely the development of these laws and be ready to take advantage of available funds. The estimated amount required would be $2,233,000. This is the estimated total construction cost ($6,350,000) less the probable Davis-Grunsky grant ($4,117,000). Several million dollars will be available annually from these acts for grants to the State of California, beginning in the 1965-66 fiscal year.

TABLE 29

DETERMINATION OF ALLOWABLE DAVIS-GRUNSKY GRANT

The maximum possible Davis-Grunsky grant is limited to 75 percent of the project construction cost ($6,350,000 x 0.75 = $4,760,000) plus the initial cost of water supply and sanitary facilities ($350,000).

Therefore the maximum possible grant is $5,110,000.

DETERMINATION OF ALLOWABLE RECREATION GRANT

Project cost allocated to recreation	$8,560,000	
Less the following items not allowed for grant 1/		
Construction cost of onshore recreation facilities	890,000	
Operation, maintenance, replacement, and future costs of installation of recreation facilities	3,342,000	
Maximum possible recreation grant	$4,328,000	
(Recreation grant is limited to 50 percent of dam and reservoir cost)		
Total project construction cost	$6,350,000	
Water supply, sanitary, and recreation facilities	1,140,000	
Dam and reservoir cost	$5,210,000	
50 percent of dam and reservoir cost	$2,605,000	
Total allowable recreation grant		$2,605,000

DETERMINATION OF ALLOWABLE FISHERIES ENHANCEMENT GRANT

Project cost allocated to fisheries enhancement 1/	$2,355,000	
Less the following items not allowed for grant		
Construction cost of onshore recreation facilities	251,000	
Operation, maintenance, replacement and future costs of installation of recreation facilities	942,000	
Maximum possible fisheries enhancement grant	$1,162,000	
(Fisheries enhancement grant is limited to 50 percent of total project cost)		
50 percent of total project cost	3,175,000	
Total allowable fisheries enhancement grant		1,162,000

DETERMINATION OF WATER SUPPLY AND SANITARY FACILITIES GRANT

Total construction cost	$ 360,000	
Cost of oversizing for future facilities	10,000	
Total allowable water supply and sanitary facilities grant		350,000
TOTAL ALLOWABLE DAVIS-GRUNSKY GRANT		$4,117,000

TOTAL PROJECT CONSTRUCTION COST	= $6,350,000
TOTAL DAVIS-GRUNSKY GRANT	= 4,117,000
FUNDS REQUIRED FROM ANOTHER SOURCE	= $2,233,000

1/ Assumed to be in same proportion as recreation and fisheries enhancement benefits, 78 percent for recreation and 22 percent for fisheries enhancement.

Local Funds through Bonding. Recognizing the large primary and secondary benefits which would accure to Siskiyou County and especially the area surrounding the project, the local citizens could elect to sell bonds to raise money for a portion of the construction cost. This would be most likely, of course, after all other sources of federal and state grant money are exhausted.

Assuming that the $4,117,000 was available from state funds but that the additional $2,233,000 was not available from another source, an estimate was made of the tax increase required for Siskiyou County to pay off a $2,500,000 bond at 3.5 percent interest over a 50-year period.

The 1963-64 assessed valuation of property subject to tax in Siskiyou County was $75,184,000 and the tax rate was $2.26 per $100 assessed valuation. To pay off the bond described above it would be necessary to increase the tax rate to $2.40--an increase of about $0.14 per $100 valuation. This would be within the legal limits for bonding of the county but would of course be subject to a vote of the residents of the county.

Project Operation and Maintenance Funds

Before any funds would be granted or loaned to an agency sponsoring the project construction, it would be necessary for the agency to show how the project would be operated and maintained after construction. An accounting of where operation and maintenance funds would come from would also be required. This is necessary to reasonably guarantee the loaning or granting agency that the loan would be repaid or that the benefits expected from use of the grant money would actually be accrued.

Historically, revenues from operation of State Parks and other recreation areas average less than one-half the operation and maintenance costs. Because of the probability that project revenues will not cover operation and maintenance costs, the Siskiyou County Flood Control and Water Conservation District is not anxious to retain responsibility for operation and maintenance of the project.

Assembly Bill No. 141 introduced into the 1965 regular session of the California Legislature by Assemblywoman Davis on January 11, 1965, and amended on March 4, 1965, provided that:

"Upon completion of the construction of the Box Canyon Dam and Reservoir in Siskiyou County, the department [Parks and Recreation], upon written request therefor being made by the Siskiyou County Flood Control and Water Conservation District, or the Mt. Shasta Recreation and Park District if it constructs the dam and reservoir, shall cause the dam and reservoir and all real property, including recreation facilities, acquired by the district in connection therewith to be operated and maintained as a part of the state park system pursuant to a written agreement with the district; provided, that the department shall be required to comply with this section only to the extent that appropriations are made by the Legislature for such compliance."

No action was taken on this bill. However, if similar legislation is enacted by the Legislature at some later date, it could provide a sufficient guarantee to a loan or grant agency that the project would be adequately operated and maintained. If such legislation is not enacted, the constructing agency would be required to show an alternative scheme for project operation and maintanance.

Proposed Plan for Financing Project Construction and Operation

The most readily apparent plan for making the Box Canyon Project a reality places the burden of further action on a local agency such as the Siskiyou County Flood Control and Water Conservation District. Since this agency has shown considerable interest in development of the project, since it has the capacity to represent the entire county, and since it has already been determined to be an eligible agency for receiving a State Davis-Grunsky grant, it appears to be the logical constructing agency.

The agency should attempt to obtain construction funds through the State Davis-Grunsky Act and from the federal government through the Land and Water Conservation Act of 1965, or the Public Works and Economic Development Act of 1965.

This feasibility report (with slight revisions) could be submitted by the agency to the State to fulfill the requirement of a feasibility study in support of a $4,117,000 recreation and fisheries enhancement grant through the Davis-Grunsky Act. This should be done as soon as possible.

The agency should contact the proper federal and state authorities to determine the procedure to be followed in requesting grants and loans for the $2,233,000 needed for the balance of the project construction cost.

As stated in an earlier section, the federal funds will come to the State and some of the funds will then be disbursed by the State to qualifying lesser agencies. The procedures for allocation of funds to be received by California under the provisions of the Land and Water Conservation Fund have

been considered by an interagency committee appointed by the State Administrator of Resources. The committee has recommended that these funds should not be disbursed on the basis of a set formula, but rather an attempt should be made to achieve a geographical distribution statewide based upon demands for recreational facilities, whether by State or local agencies. It appears that the local agency should coordinate its activities closely with the Administrator of Resources and should obtain support for acquiring a grant from these funds through their legislators.

The best plan for operation and maintenance of the recreation facilities, from the standpoint of the local agency, would be to let the State Department of Parks and Recreation take over the recreation portion of the project and operate it as a state recreation area. This was discussed more fully in a previous section.

If legislation to have the Department of Parks and Recreation operate and maintain the recreation features of the project is not enacted, the local agency could retain operation and maintenance of the entire project. However, the agency should be aware that project operation costs may exceed project revenues.

In summary, the best plan for financing the construction and operation of the Box Canyon Project at the present time appears to be:

(1) that a local agency such as the Siskiyou County Flood Control and Water Conservation District assume responsibility for the project and obtain state and federal grants for as much of the project construction costs as possible, and

(2) that the sale of local bonds be considered for financing those costs not covered by state and federal grants, and

(3) that the constructing agency either attempt to obtain legislation which would enable the State Department of Parks and Recreation to operate the recreation facilities of the completed project as part of the State Park System, or that the agency act as operator through the collection of user fees.

LEGEND

WATERSHED BOUNDARIES

SACRAMENTO RIVER ABOVE DELTA STREAM GAGING STATION

SACRAMENTO RIVER ABOVE MT. SHASTA STREAM GAGING STATION

50 LINES OF EQUAL MEAN ANNUAL PRECIPITATION IN INCHES

STREAM GAGING STATIONS

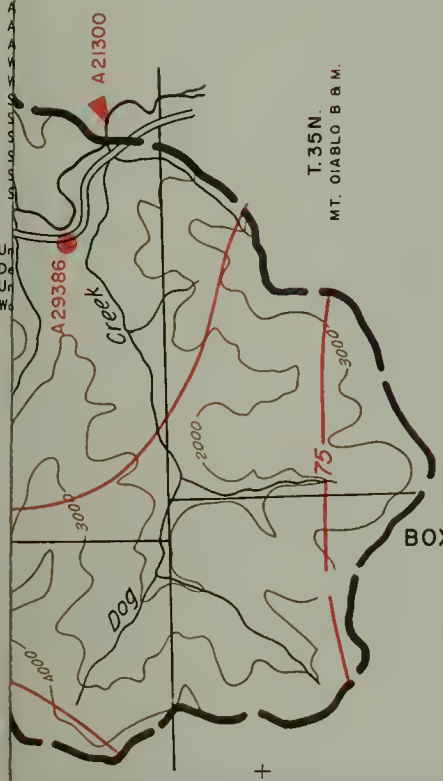
A21300 CONTINUOUS RECORDER

WRB-1 TEMPORARY CONTINUOUS RECORDER

S-1 TEMPORARY STAFF GAGE

A34672 PRECIPITATION STATION

16 SNOW COURSE



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH

BOX CANYON PROJECT FEASIBILITY STUDY

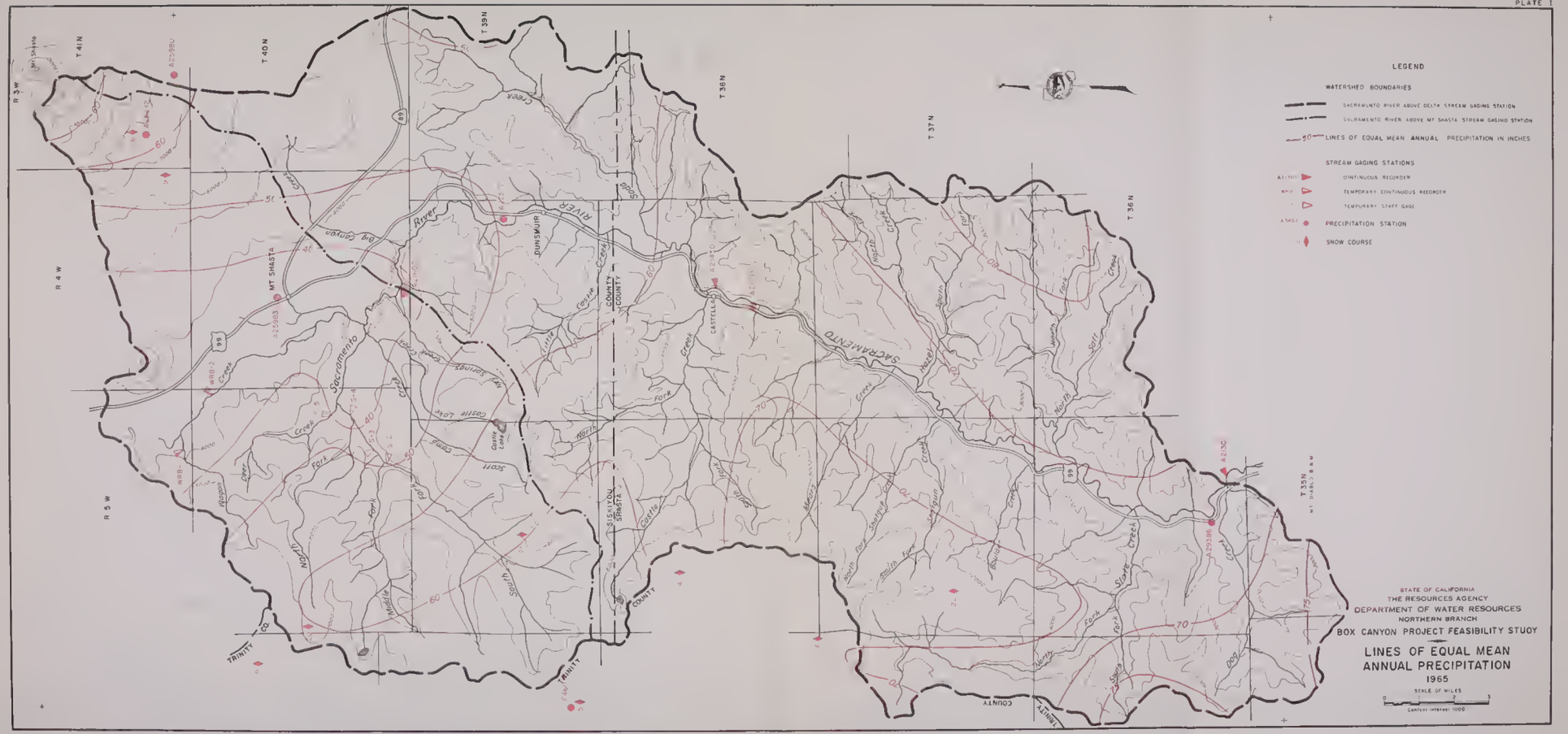
LINES OF EQUAL MEAN ANNUAL PRECIPITATION
1965

SCALE OF MILES
0 1 2 3
Contour Interval 1000'

PLATE 1

Identification Number	Name	Operator	Period of Record	Estimated Average Annual Precipitation (in inches) 1905-1953	Estimated Average April 1 Water Content (in inches) 1930-1958
Precipitation Stations					
A25990	Mt. [illegible] Lk. Basin	USWB	1958-date		
A25982	Mt. Shasta Ski Shop	USWB	1947-date	93.9	
A25983	Mt. Shasta City	USWB	1838-date	53.5	
A22572	Dunsmuir Ranger Station	USWB	1889-date	51.2	
A21576	Castella	Private	1953-date	62.5	
A29366	Vollmers	USWB	1937-date	62.7	
Fish52	Mumbo Basin	USWB	1948-date	69.8	
Snow Courses					
9	Deadfall Lakes	DWR	1946-date		33
14	Sharon	DWR	1947-date		29
15	Mumbo Basin	DWR	1947-date		26
18	Highland Lakes	DWR	1947-date		32
19	Mount Shasta	DWR	1930-date		61
20	Sand Flat	DWR	1945-date		61
20	North Fork Sacramento	DWR	1936-date		23
21	Gray Rock Lakes	DWR	1947-date		44
22	Slate Creek	DWR	1945-date		28
Gaging Stations					
A21300	Sacramento River at Delta	USGS	1943-date		
A21430	Sacramento River at Castella	USGS	1931-23		
A21400	Sacramento River near Mt. Shasta	USGS	1959-date		
#SB-1	Wagon Creek at Mills Ranch	#RB	May-Dec. 1960		
#SB-2	Wagon Creek below Mills Ranch	#RB	May-Dec. 1960		
S-1	Wagon Creek below Cold Creek	DWR	July-Dec. 1960		
S-2	South Fork Sacramento River at Bridge	DWR	July-Dec. 1960		
S-3	Sacramento River between Middle Fork & North Fork	DWR	July-Dec. 1960		
S-4	Sacramento River between North Fork & Deer Creek	DWR	July-Dec. 1960		
S-5	Deer Creek at Bridge	DWR	July-Dec. 1960		
S-6	Scott Camp Creek at Bridge	DWR	July-Dec. 1960		

USWB-United States Weather Bureau
DWR Department of Water Resources
USGS-United States Geological Survey
#RB Water Rights Board



LEGEND

al — STREAM ALLUVIUM – CONSISTS OF BOULDERS, GRAVEL AND SAND. ROCKS ARE COMPOSED OF VARIOUS INTRUSIVE AND VOLCANIC TYPES.

sw — SLOPEWASH – PREDOMINANTLY A BROWN SANDY TO CLAYEY SILT WITH SOME GRAVEL. DEPOSIT IS THIN AND PINCHES OUT TOWARD RIVER.

t — TERRACE DEPOSITS – THICK DEPOSITS OF COARSE GRAVEL IN THE UPSTREAM PORTION WHICH GRADE LATERALLY DOWNSTREAM INTO SILTY GRAVEL AND SAND AND ULTIMATELY TO FINE-GRAINED LAKE SEDIMENTS ALONG SCOTT CAMP CREEK

s — LAKE AND INTERBEDDED STREAM DEPOSITS – CONSISTS OF COMPACTED BEDS OF SAND SILT AND CLAY WITH VOLCANIC ASH. PROBABLY UNDERLIES ALLUVIUM IN EASTERN PORTION OF RESERVOIR.

f — ALLUVIAL FANS – CONSISTS OF POORLY SORTED, ANGULAR DEBRIS FROM RAINBOW RIDGE.

sd — SHASTA GLACIAL DRIFT – GRAVELLY SANDY SILT CONTAINING NUMEROUS COBBLES AND LARGE BOULDERS.

rc — RED CLAY - OCCURS AS A THICK RESIDUAL SOIL CONTAINING HALLOYSITE CLAY. DERIVED FROM THE WEATHERING OF VOLCANIC TUFF.

vt — VOLCANIC TUFF – PINK TO GREY FINE-GRAINED ROCK WITH RELATIVELY LOW DENSITY DIRECTLY OVERLIES CASCADE VOLCANICS.

va — CASCADE VOLCANICS – FINE-GRAINED, GREY TO DARK GREY ANDESITE WITH ABUNDANT SUBPARALLEL, FRACTURES AND A VERTICAL JOINT PATTERN.

m — PALEOZOIC ROCKS – META-SEDIMENTS AND META-VOLCANICS. WEATHERED ROCK AND SLOPEWASH AT BASE OF RAINBOW RIDGE PROVIDE A SOURCE OF IMPERVIOUS MATERIALS.

GEOLOGIC CONTACT

BOUNDARY OF CONSTRUCTION MATERIALS BORROW AREA.
IMPERVIOUS MATERIALS, B-2, B-5, B-6
SEMI-PERVIOUS MATERIALS, B-1, B-4
PERVIOUS MATERIAL, B-3

PORTION OF BORROW AREA USED IN DESIGN OF DAM AS SHOWN ON PLATE 3

NOTE: GRID BASED ON CALIFORNIA COORDINATE SYSTEM ZONE 1

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH

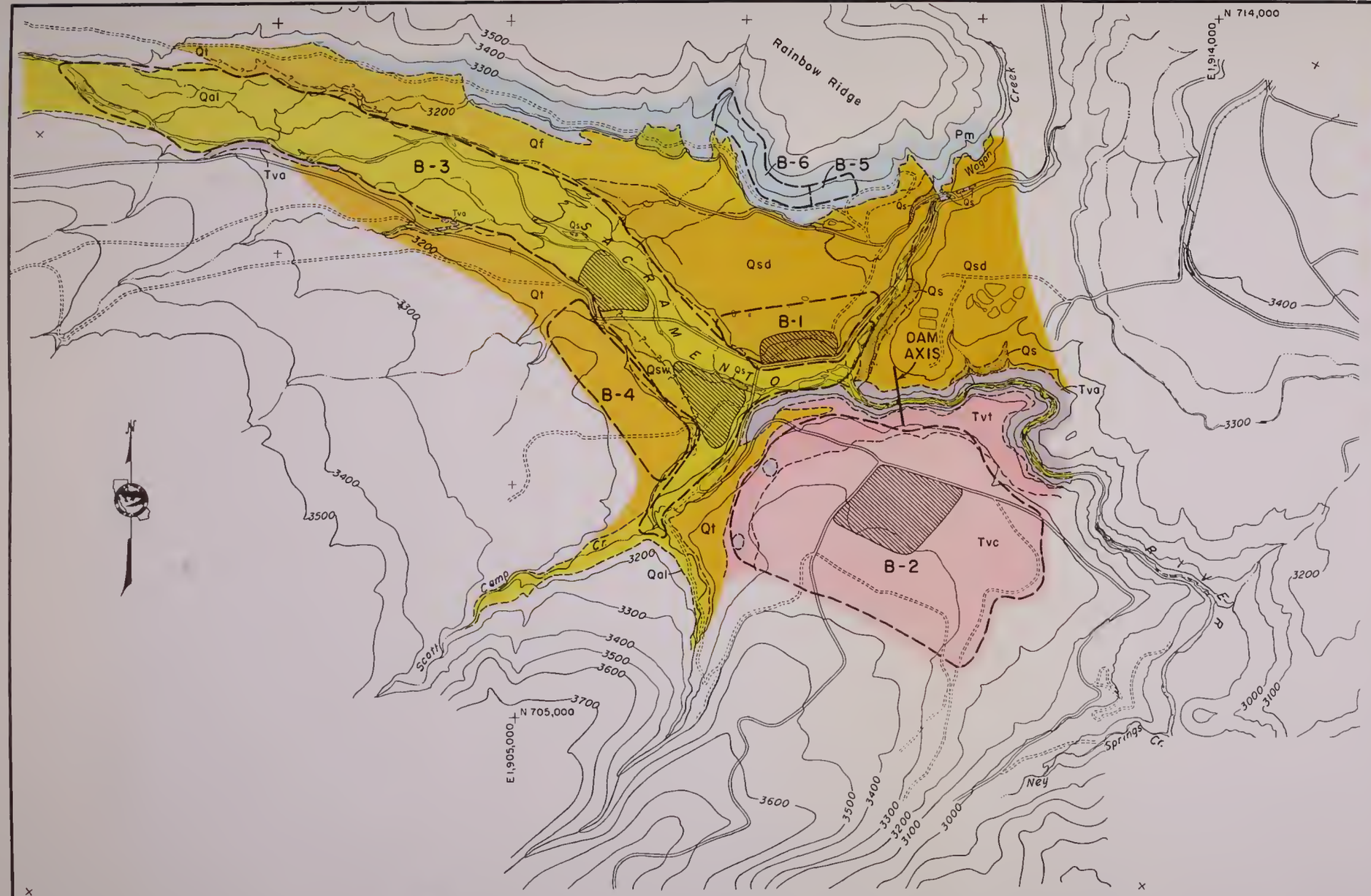
BOX CANYON PROJECT FEASIBILITY STUDY

RESERVOIR GEOLOGY
AND
LOCATION OF CONSTRUCTION MATERIALS

1965

SCALE OF FEET
0 1000 2000

Contour Interval 100'



LEGEND

QUATERNARY

- **Qal** — STREAM ALLUVIUM – CONSISTS OF BOULDERS, GRAVEL AND SAND ROCKS ARE COMPOSED OF VARIOUS INTRUSIVE AND VOLCANIC TYPES.
- **Qsw** — SLOPEWASH – PREDOMINANTLY A BROWN SANDY TO CLAYEY SILT WITH SOME GRAVEL. DEPOSIT IS THIN AND PINCHES OUT TOWARD RIVER.
- **Qt** — TERRACE DEPOSITS – THICK DEPOSITS OF COARSE GRAVEL IN THE UPSTREAM PORTION WHICH GRADE LATERALLY DOWNSTREAM INTO SILTY GRAVEL AND SAND AND ULTIMATELY TO FINE-GRAINED LAKE SEDIMENTS ALONG SCOTT CAMP CREEK
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- **Qsd** — SHASTA GLACIAL DRIFT – GRAVELLY SANDY SILT CONTAINING NUMEROUS COBBLES AND LARGE BOULDERS.

TERTIARY

- **Tvc** — RED CLAY – OCCURS AS A THICK RESIDUAL SOIL CONTAINING HALLOYSITE CLAY. DERIVED FROM THE WEATHERING OF VOLCANIC TUFF.
- **Tvt** — VOLCANIC TUFF – PINK TO GREY FINE-GRAINED ROCK WITH RELATIVELY LOW DENSITY DIRECTLY OVERLIES CASCADE VOLCANICS
- **Tva** — CASCADE VOLCANICS – FINE-GRAINED, GREY TO DARK GREY ANDESITE WITH ABUNDANT SUBPARALLEL FRACTURES AND A VERTICAL JOINT PATTERN.

PALEOZOIC

- **Pm** — PALEOZOIC ROCKS – META-SEDIMENTS AND META VOLCANICS WEATHERED ROCK AND SLOPEWASH AT BASE OF RAINBOW RIDGE PROVIDE A SOURCE OF IMPERVIOUS MATERIALS

GEOLOGIC CONTACT

BOUNDARY OF CONSTRUCTION MATERIALS BORROW AREA.
IMPERVIOUS MATERIALS, B-2, B-5, B-6
SEMI-PERVIOUS MATERIALS, B-1, B-4
PERVIOUS MATERIAL, B-3

PORTION OF BORROW AREA USED IN DESIGN OF DAM AS SHOWN ON PLATE 3

NOTE: GRID BASED ON CALIFORNIA COORDINATE SYSTEM ZONE 1

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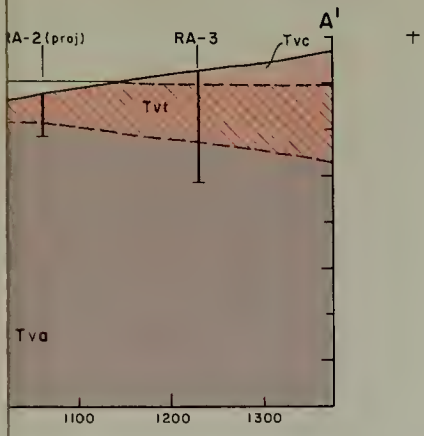
NORTHERN BRANCH

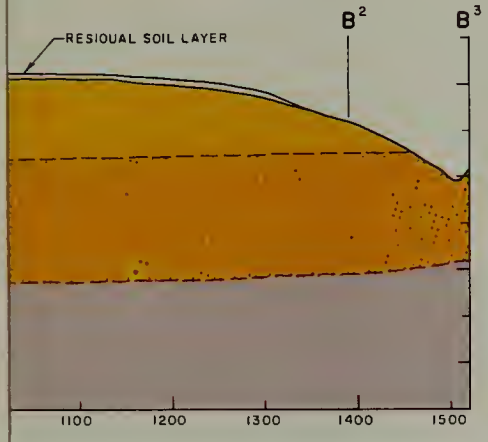
BOX CANYON PROJECT FEASIBILITY STUDY

RESERVOIR GEOLOGY AND LOCATION OF CONSTRUCTION MATERIALS

1965

SCALE OF FEET
0 1000 2000
Contour Interval 100'





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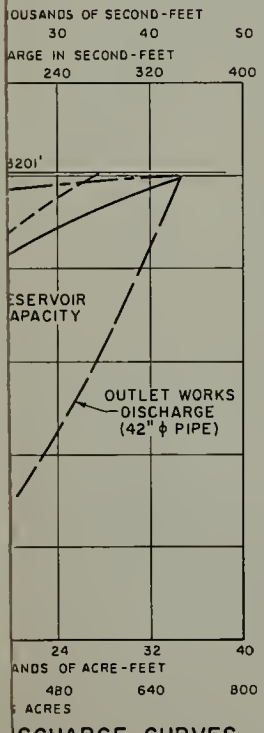
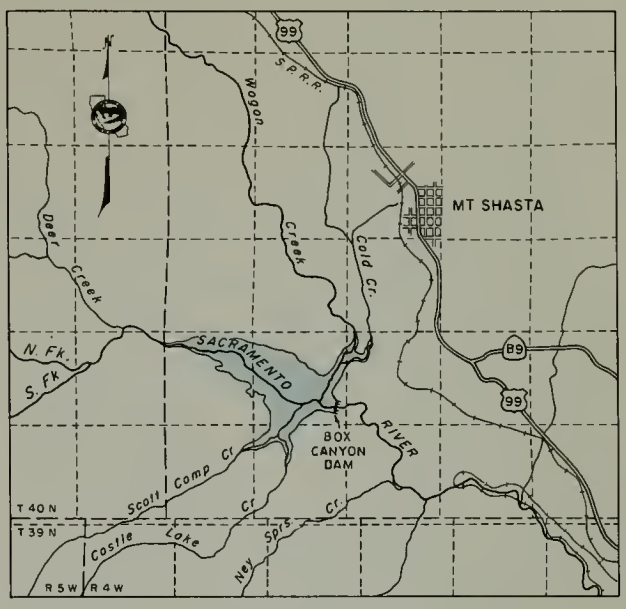


SCHARGE CURVES



LOCATION MAP

SCALE OF MILES

0 1 2

LEGEND

QUATERNARY

Qal — STREAM GRAVEL - CONSISTS OF BOULDERS, GRAVEL AND SAND. ROCKS ARE COMPOSED OF VARIOUS INTRUSIVE AND VOLCANIC TYPES.

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TERTIARY

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SYMBOLS

CONTACT

CONTACT, APPROXIMATELY LOCATED

CONTACT, PROJECTED

CONTACT, INFERRED ONLY

3,300 / 10,000 — CONTACT BASED ON SEISMIC PROFILE. NUMBERS INDICATE VELOCITY OF SHOCK WAVES IN FEET PER SECOND.

CONTACT, CONCEALED BENEATH Qal

LA-1(proj) — DIAMOND DRILL HOLE. Proj. INDICATES HOLE PROJECTED INTO SECTION.

BA-5 — AUGER DRILL HOLE

LA-T2 — TRENCH FOR SUBSURFACE EXPLORATION

SP2 LINE A SP1 — SEISMIC LINE AND SHOT POINTS

STATE OF CALIFORNIA
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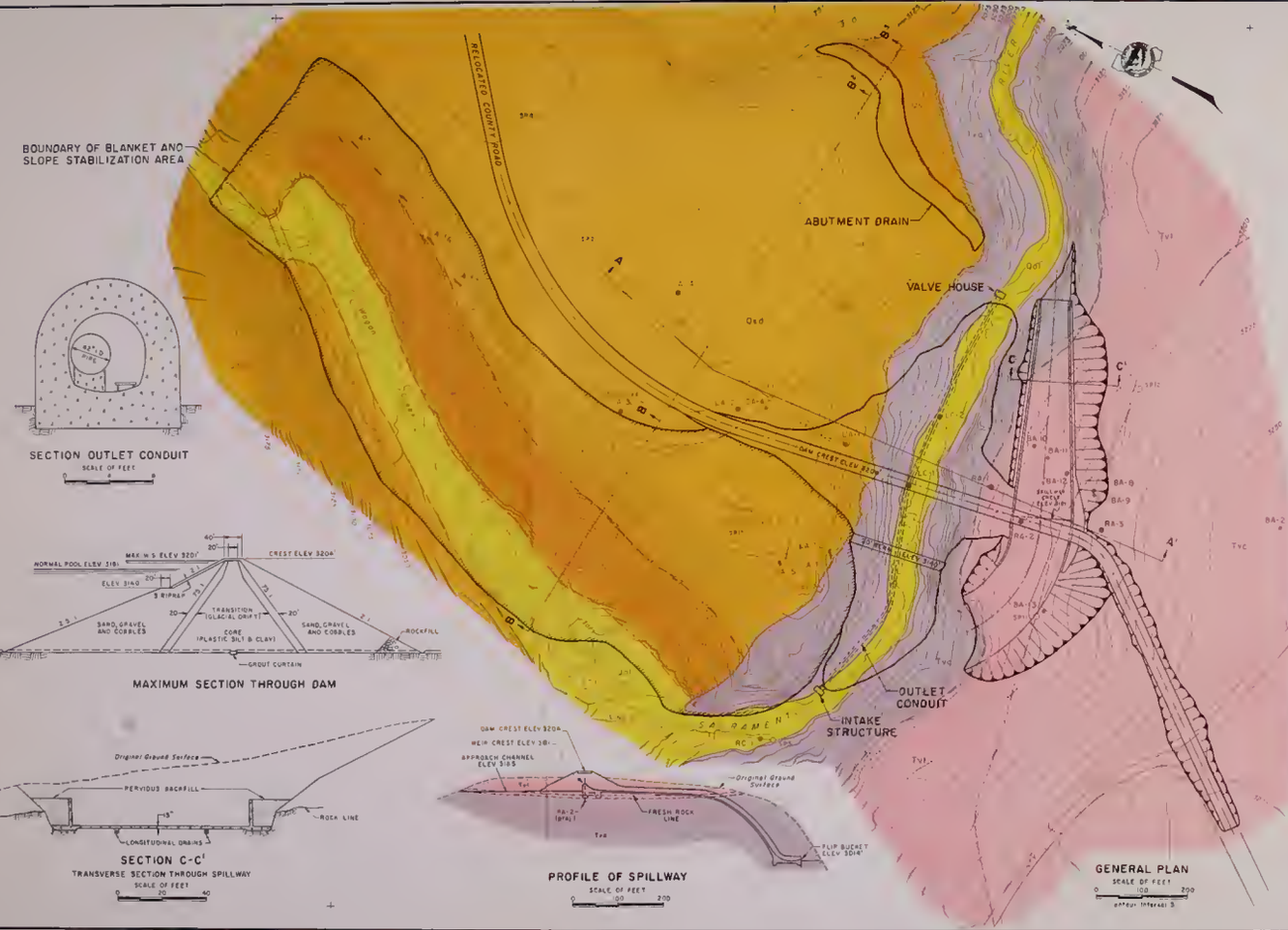
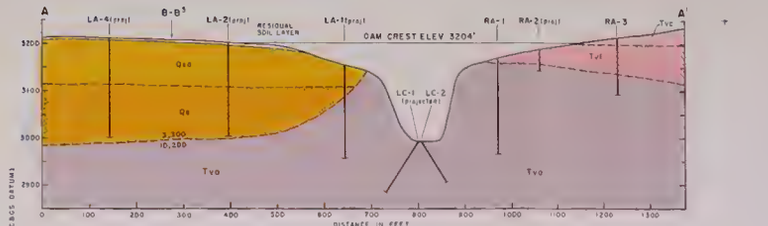
NORTHERN BRANCH

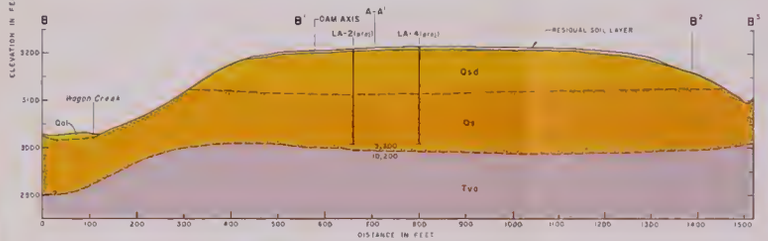
BOX CANYON PROJECT FEASIBILITY STUDY

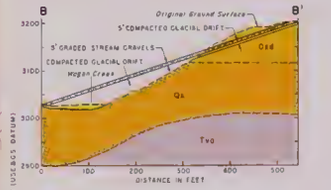
BOX CANYON DAM
ON
SACRAMENTO RIVER

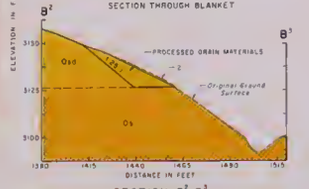
1965

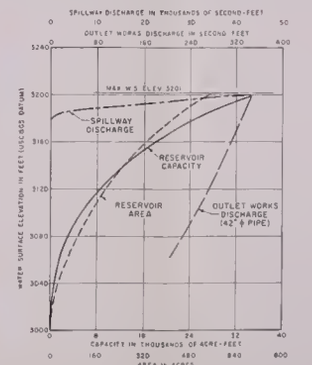


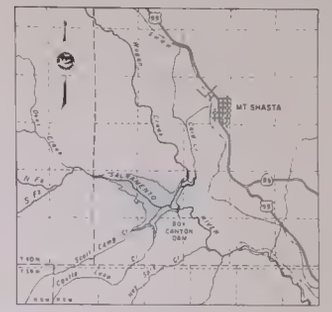












LEGEND

QUATERNARY

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SYMBOLS

- CONTACT
- CONTACT APPROXIMATELY LOCATED
- CONTACT PROJECTED
- CONTACT INFERRED ONLY
- CONTACT BASED ON SEISMIC PROFILE, NUMBERS INDICATE VELOCITY OF SHOCK WAVES IN FEET PER SECOND
- CONTACT CONCEALED BENEATH QAL
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- AUGER DRILL HOLE
- TRENCH FOR SUBSURFACE EXPLORATION
- SEISMIC LINE AND SHOT POINTS

STATE OF CALIFORNIA
THE RESOURCES AGENCY
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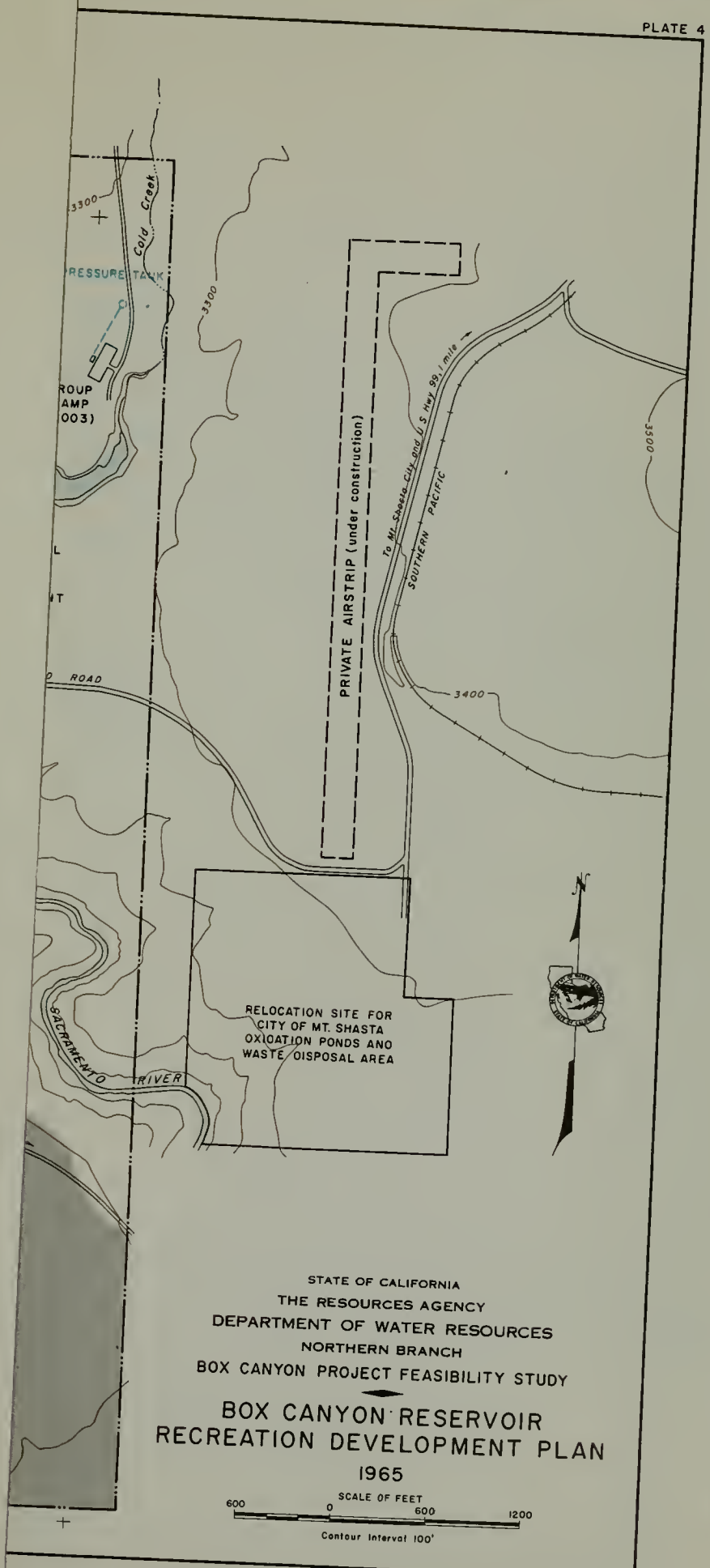
NORTHERN BRANCH

BOX CANYON PROJECT FEASIBILITY STUDY

BOX CANYON DAM ON SACRAMENTO RIVER

1965

PLATE 4



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
BOX CANYON PROJECT FEASIBILITY STUDY

BOX CANYON RESERVOIR RECREATION DEVELOPMENT PLAN

1965

SCALE OF FEET
600 0 600 1200

Contour Interval 100'

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
BOX CANYON PROJECT FEASIBILITY STUDY

BOX CANYON RESERVOIR RECREATION DEVELOPMENT PLAN 1965

SCALE OF FEET
600 0 600 1200
Contour Interval 100'